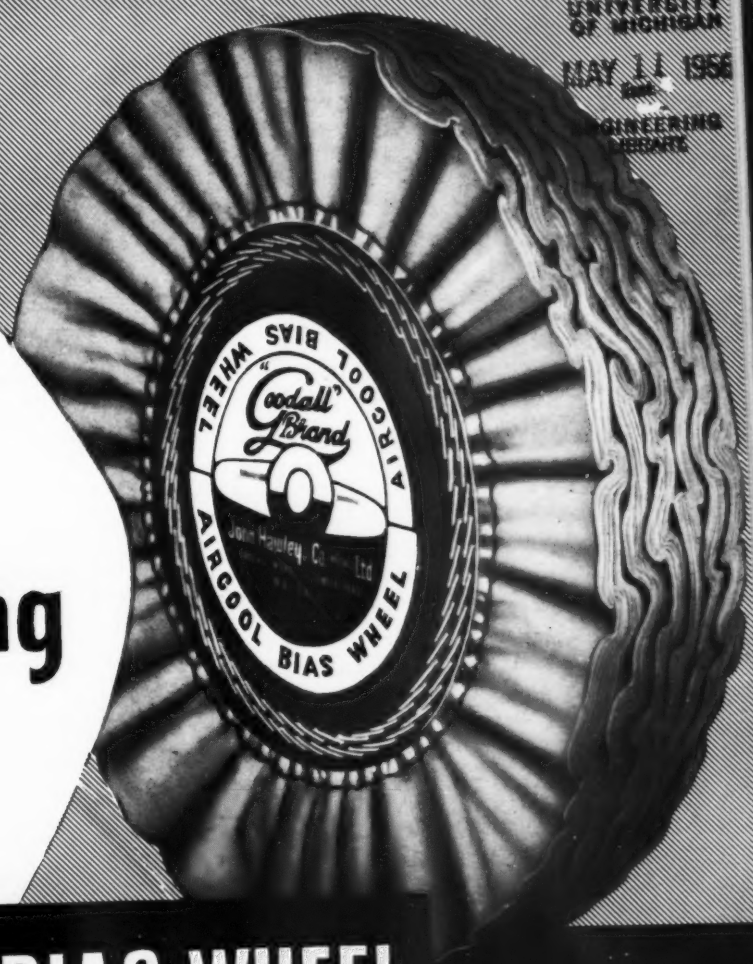
metal finishing

Vol. 1 No. 4 (new series) APRIL, 1955

UNIVERSITY OF MICHIGAN
MAY 11 1956
ENGINEERING

Save £££'s in polishing costs WITH THE



Aircool BIAS WHEEL

Why do refrigerators
turn a cold shoulder upon colour ? As colour
makers with a world-wide reputation and considerable experience
of colour treatments for vitreous enamels, we cannot but wonder if a false sense of logic is behind it all. There is no virtue in the exterior of a refrigerator emulating its inside. After all, a cheerful colourful refrigerator is no less efficient, or hygienic, and it is just as easy to keep clean. If refrigerators were allowed to perform their cold duties cheerfully, we are convinced that buyers would welcome them all the more warmly.

Blythe COLOUR WORKS LIMITED
CRESSWELL · STOKE-ON-TRENT

. . . the home of the world's best colours

metal finishing Journal

APRIL, 1955 — AN INDUSTRIAL NEWSPAPERS PUBLICATION — Vol. 1 No. 4 (New Series)

Editor: JOHN HOOPER
Assistant Editor: E. H. LLOYD, A.I.M., A.C.T.(Birm.)
Southern Area Manager: J. SUMNER-MOORE
Production Manager: R. J. LOVELL
Managing Editor: ALASTAIR McLEOD, F.I.M.
Advertisement Director: F. BARRINGTON HOOPER, B.A.
Northern Area Manager: G. P. ELLIOTT
Circulation Manager: E. T. GRIFFITHS
Scottish Area Manager: T. H. SMITH
Publisher: H. J. DWYER

Official Organ of the

INSTITUTE OF VITREOUS ENAMELLERS

President:
SIR GEORGE BRIGGS

Chairman:
A. BIDDULPH

Secretary:
J. D. GARDOM
John Gardom & Co., Ripley, Derby
Telephone: Ripley 136

Published on the 15th of each month by

INDUSTRIAL NEWSPAPERS LIMITED

Chairman: Harold Jeans
Managing Director: Barrington Hooper, C.B.E.
Commercial Director: F. Barrington Hooper, B.A.
Secretary: E. G. Weston

JOHN ADAM HOUSE
17-19 JOHN ADAM STREET
ADELPHI, LONDON, W.C.2

Telephone: TRAfalgar 6171 (P.B.X.)
Telegrams: Zacatecas, Rand, London

Subscription Terms:
Home and Overseas 24*s.* per annum prepayable
Single copies 2*s.* (2*s.* 4*d.* post free)

THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING AND ALL METAL-FINISHING PROCESSES.

THE EDITOR IS PREPARED TO CONSIDER FOR PUBLICATION ANY ARTICLE COMING WITHIN THE PURVIEW OF METAL FINISHING JOURNAL AND ALL SUCH ARTICLES ACCEPTED WILL BE PAID FOR AT THE USUAL RATES.

Contents

"Skin Deep" 143

Talking Points 144
"Platelayer"

A Simple Non-destructive Thickness Gauge for Electrodeposits 145
A. R. Heath, B.Sc.

The Application of Rubber and Plastics to the Metal Finishing Industry 151
E. W. Mulcahy

The Nature and Significance of Mill Additions in Vitreous Enamelling 155
J. J. Guy, B.Sc., A.C.G.I., A.M.I. Chem.E.

The Work of the B.I.S.R.A. Coatings Research Laboratory, Sketty Hall, Swansea 159
S. S. Carlisle, M.Sc., A.M.I.E.E.

Overseas Review 166
Scrutator

Modern Methods for the Measurement of Metal Surface Finish 168
Leo Walter, A.M.I.Mech.E.

A Students Guide to Examination Courses in Metal Finishing—Part II 177
A. Alexander

Finishing News Review 183

Plant, Processes and Equipment 188

THREE ELEPHANT

Brand

BORON PRODUCTS

are now available packed in

Polythene

LINERS

in hessian bags

at

NO EXTRA COST!

The Polythene liner is now standard packing for BORAX, BORIC ACID, V-BOR and PYROBOR when packed in hessian bags.

ADVANTAGES OF POLYTHENE LINERS

★ **Stronger and more durable than paper liners.**

★ **Less risk of contaminating contents with fibres.**

★ **Best possible protection against absorption of moisture and caking of contents.**

★ **The contents are more easily emptied.**

Our THREE ELEPHANT BRAND BORON PRODUCTS are still available packed in 6-ply paper bags for users who prefer this package.

BORAX & CHEMICALS LTD

KINGS BOURNE HOUSE, 229 HIGH HOLBORN, LONDON, W.C.1

'Phone: HOLborn 6518 Cables: Boraxchem, London 'Grams: Boraxchem Phone London

KIN DEEP

THE duplex purpose of applying a finish to a metal surface is to protect it from the corrosive influences of its environment and to increase its attractiveness and eye-appeal to potential purchasers. These two aims must be regarded as being mutually interdependent, as any finish, which was not corrosion resistant, would rapidly become unattractive, and the use of a corrosion-resistant coating, by preventing the accumulation of unsightly corrosion products, must increase eye-appeal. The main endeavour of those responsible for the commercial development and application of metal finishes is to achieve this twin aim as effectively and economically as possible by striking a satisfactory compromise between the two fundamental requirements.

As every metal-finishing process consists of the production or application of a film or coating to a metal surface, it is not unnatural that the thickness of the film is of vital importance in relation to its performance and protective quality. Some coatings, in particular metallic coatings, produced by electrodeposition or hot dipping, are almost impossible to produce without some degree of porosity, which can only effectively be reduced (at the present time) by increasing the coating thickness to uneconomic limits. On the other hand, a vitreous-enamel coating, as at present applied, is to all intents and purposes completely non-porous, but is normally ten to twenty times the thickness of an electrodeposited coating. Paint films, or as they are now coming to be known, organic finishes, fall between these extremes, both with regard to thickness and porosity.

It can thus be seen that the optimum performance is obtained from electrodeposits by increasing their thickness, a fact which is reflected in the standard specifications laid down for them; this however, is wasteful in its consumption of both time and costly materials, and current research is directed towards reducing the degree of porosity to permit of the application of thinner coatings.

The application of vitreous enamel in thicknesses above 0.010 in. increases the susceptibility of this coating to chipping in service, and here again the aim, although for a different reason, is to achieve still thinner coatings without reducing their protective value. Similarly with paint there is a desirable maximum to the thickness applied beyond which both cost and performance tend to be unsatisfactory.

In every field of metal finishing the close and accurate control of coating thickness is of fundamental importance to the production of a finish with a satisfactory performance. Considerable effort has been expended in recent years in developing methods for measuring coating thickness, some highly successful, some less so, the greater degree of success being achieved by methods involving damage to, or destruction of the coating.

The growth of the science of electronics however, has, in this field as in so many others, put new tools and new powers into the hands of the research worker. The name of the British Non-Ferrous Metals Research Association has long been associated with the problem of the determination of coating thickness, and for some years now the B.N.F. jet test has been adopted as standard procedure in many quarters for the assessment of the thickness of electrodeposits. Now once again B.N.F. have pioneered the development of a non-destructive electronic instrument, of which a description is published elsewhere in this issue, and which will be exhibited at the forthcoming Exhibition of the Physical Society at the New Horticultural Hall. Now that equipment is being made available to the metal-finishing industry, which permits of the exact measurement of the thickness of applied coatings it can be hoped that further progress will be made towards making technically possible the thinner coatings which both economics and performance show to be desirable.

Talking Points by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

THE CONFERENCE INDUSTRY

THOSE attending the Institute of Metal Finishing Conference next month will have the satisfaction of knowing that they are supporting the conference industry as well as their own. There are now over 600 organizations holding major conferences in this country annually, yet accommodation available for them in the form of hotels and halls suitable for meetings is pathetically small. It is, in fact, almost restricted to seaside resorts out of season, as most of the larger cities are unable to provide for sizeable conferences at all. Indeed, they often have inadequate accommodation even for normal numbers of business visitors. Across the Atlantic the economic importance of conferences is seen from the fact that 40 per cent of the annual revenue of the two largest hotels in Chicago is derived from them. It is unlikely that Birmingham, for instance, will ever have a Conference Hall like that in Chicago, housing over 12,000 people, but until our industrial cities have even minimal accommodation, delegates will have to make their way to holiday resorts, however unwillingly.

UNINTELLIGIBLE INTELLIGENCE

HOWEVER excellent the results of research development may be, ultimately their effectiveness depends on the transmission of the information to industry. This is because in the last analysis the two essentials are production and distribution. Yet the means of communication between science and industry are still very imperfect, as was borne out in the report of a recent discussion organized by the British Psychological Society.

Amongst items stressed was the importance of good illustrations in conveying information; the quality of advertising literature was commended, although the reluctance of British advertisers to state prices was considered a hindrance. With scientific journals the time-lag in publication and the style in which many scientific papers were written constituted the most serious obstacles to their effective utilization. Put more crudely, this means that they were unintelligible to many potential users.

In the case of technical advances which have been taken up by commercial interests, the steps needed to put the ideas across to those who will have to apply them are usually well taken care of by experienced sales organizations with sufficient finance at their disposal. It is principally with those developments in which there happens to be no commercial or sales element that the difficulties occur. One can think of a number of highly practical improvements which have received only limited application because there is nothing in them which anybody considered to be saleable. There are, however, signs of progress. The British Non-Ferrous Metals Research Association now issues a publication called "B.N.F. Reviews" which presents the results of its researches to its members in broad outline very attractively and succintly, so that managements can readily assimilate the point of the work described.

A similar idea in a different field is the new Monthly Summary of Automobile Engineering literature consisting of very full and simplified selected abstracts; these are much more useful to the busy executive than the usual kind of abstract bulletin, which is more often than not a glorified list of titles of papers.

Most people agree that more specialized reviews of this kind are needed.

HEAT BY THE YARD

There must be many applications where it would be very useful to be able to apply a source of heat at low temperature to containers, pipe-lines, etc., easily and quickly, and it is interesting to note that thermostatically controlled, waterproofed and insulated electrical heating tapes have been developed to enable this to be done. Amongst other uses for such tapes in the finishing industries are the prevention of crystallization in tanks and pipe-lines during cold weather and the warming of viscous materials such as paints to facilitate flow. The fact that the tapes can be readily applied and removed as and when required is advantageous.

END-POINT

At the time the recent restrictions on hire purchase were announced, a furniture store arranged for a local firm to fix a sign on its premises over the week-end. When the owner of the out-plating business next door arrived on Monday morning he was flabbergasted to find a huge poster pasted across his window which read:

VERY LOW DEPOSITS
PAYMENT IN TWO YEARS

A Simple Non-Destructive Thickness Gauge For Electrodeposits*

described by A. R. HEATH, B.Sc.†

INTRODUCTION

IN view of the wide use of electrodeposited and other metallic coatings upon metals for decoration and for protection against corrosion and wear, considerable interest attaches to the measurement of coating thicknesses by rapid, routine, non-destructive methods. Instruments have been devised for the purpose employing several different principles. Thus, magnetic(1), eddy-current(2), ultrasonic(3) and X-ray(4) thickness meters have been described, each with a particular set of advantages and limitations. For example, magnetic methods may be suitable when either the coating or the basis metal is paramagnetic, but are not well adapted to measure the thickness of a magnetic coating such as nickel upon a steel base. Eddy-current methods are more promising for this purpose but the equipment required is comparatively expensive. Ultrasonic methods fail when coatings thinner than about 0.020 in. are in question, while X-ray methods are inconvenient and require costly apparatus.

There is need for a simple, robust thickness meter capable of measuring coating thicknesses irrespective of whether coating and basis metal are magnetic and able to indicate thickness within a limit of ± 0.0001 in. with coatings up to 0.010 in. thick. The work described in this paper indicates that this may be achieved by the use of a thermoelectric method. Such methods have been used earlier for sorting stocks of materials but not until the work to be described was partly completed had any account appeared of their use for thickness measurement. However, during the course of this work Weller and Hanyz(5) gave an account of a thermoelectric sorting device and mentioned its application to coating thickness measurement. Their method is closely similar to the method described in this article, although here a different theory of the way in which the method works, and a probe design better adapted to use upon articles of complex shape, are proposed.

PRINCIPLE OF THE NEW METHOD.

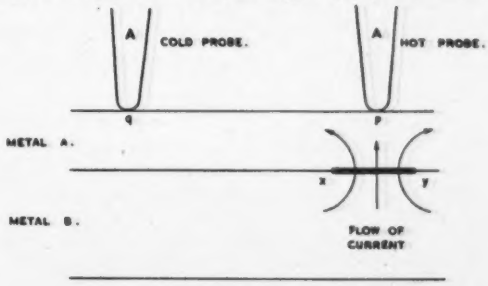
The mode of operation of the method may be envisaged in the following simple way. When a hot probe of metal *A* is applied to a cold surface of the same metal, which forms a coating upon a different metal, *B*, Fig. 1, heat flows by way of the contact so that the temperature within a region *x-y* of the interface between *A* and *B* is raised above that of the remainder. As a result of the thermoelectric potential difference which then exists between region *x-y* and the remainder of the interface, electric currents circulate in *A* and *B* in the manner indicated in the figure. Consequently, a potential difference exists between points such as *p* and *q* on the external surface of *A* and this may be measured by suitable means.

It is evident that the potential will depend on:

(i) the nature of the coating and basis metal;
(ii) the temperature difference between hot probe and work; and
(iii) probably also on such factors as the load applied to the hot probe and the shape of the probe contact.

The temperature within the region *x-y*, Fig. 1, will decrease with increase in coating thickness. Assuming therefore that the factors mentioned

Fig. 1.—Diagrammatic illustration of principle of the method.



* Communicated by The British Non-Ferrous Metals Research Association. The information given in this article was first released to members of the Association as Report No. RRA.1056 in October, 1954 and forms the subject of a patent application dated March 8th, 1954.

† Investigator, B.N.F.M.R.A.

above are kept constant there should be a relationship between coating thickness and the measured potential.

Area of Contact in Relation to Probe Shape and Loading: Contact Resistance.

For reasons elaborated in the next section it is desirable that the area of contact over which heat is transferred between probe and work should be localized and small, and that it should be reproducible from one specimen to the next of the same type.

Bowden and Tabor(6) show that this may be achieved merely by ensuring that the probe loading remains constant. They show that, whatever the contours of the two touching surfaces, the area of contact is closely proportional to the load pressing them together. Thus, $A \simeq W/p_m$, where A = area of contact, W = load and p_m = a "yield pressure" at which plastic deformation of the softer of the two materials in contact begins.

By way of example one can consider the case of a nickel probe in contact with a nickel plating. With a yield pressure of about 100,000 lb. per sq. in., and a contact pressure of 1 lb. the area of intimate contact (from $A \simeq W/p_m$) is approximately 10^{-5} sq. in.

Experimental work has shown this figure to be approximately correct.

This area must be as localized as possible and this is best achieved on a relatively flat and smooth work surface by using a hemispherical-ended probe of small radius of curvature, say about 0.015 in. There is then a contact area circular in shape and about 0.003 in. in diameter, comparable with the thickness of coating to be measured.

Heat Flow Between Probe and Work.

It is shown in the mathematical theory of heat how when the plane surface of a body is suddenly raised to and maintained at a fixed temperature above the initial temperature of the body, the temperature rise V at any subsequent time t at any point distant x below the surface may be calculated in terms of the thermal diffusivity of the material in question.

By way of example it is convenient to consider the thermal diffusivity of chromium, nickel and steel as all having the value $k = 0.15$ c.g.s. and calculate the temperature rise at various depths below the surface of a nickel/chromium plated steel block in relation to time after raising the surface temperature. The result is shown in Table I.

Clearly, in this case the temperature does not vary appreciably with depth below the surface at times exceeding 1/100 sec. and thicknesses less than 1 mm. and correspondingly the thermoelectric potential which could be measured would not be proportional to coating thickness. When, on the other hand, heat is supplied by way of a point source applied to the surface, the temperature rise V at time t and distance x from the point of application is proportional to $1/x$ of the values given in Table I.

In this case it may be shown:

(i) that after the first 1/100 second a substantially steady-state temperature gradient exists in the body around the point at which the probe is applied.

(ii) that the temperature gradient is steep, a considerable fall of temperature occurring in a distance of 0.001 in. from the point of application.

Although detailed calculation for a finite area of contact is difficult, it appears probable that the amount of heat flow in this practical case should be small, so that neither the test piece as a whole, nor the probe as a whole will suffer any significant change of temperature in periods of a few minutes.

It may be noted that the effect of a thin coating of chromium such as is used in decorative finishing of nickel plate is expected to be negligible since the opposing thermoelectric forces on either face of the chromium will cancel, the temperature drop across the thickness of the chromium being so small.

It is also to be expected that unless the test-piece to which the probe is applied is very thin, say less than 0.02 in., the result should be substantially independent of the thickness of the article, and further that the area over which average thickness

TABLE I.

Plane Heating: Temperature (Expressed as a fraction of the Surface Temperature Rise) for Various Times and Distances Below the Surface.

Distance below Surface x (cm.)		0.001	0.01	0.1	1	10
Time after start	10^{-2}	0.99	0.89	0.16	0	0
	1	1	0.99	0.89	0.16	0
t (sec.)	10^{2}	1	1	0.99	0.89	0.16

is measured by the probe will be very small indeed, so that "edge effects" should be negligible.

Finally, it may be added that the material of which the probe is made need not be the same as that of the coating. If it is different, a second thermoelectric e.m.f., arising at the probe/coating junction, is included in the measuring circuit but the total output signal still varies with the coating thickness.

EXPERIMENTAL STUDY OF THE METHOD

It is not readily possible to calculate precisely the thermal and electrical conditions obtaining in any particular practical case and the conditions for successful operation are best found by experiment. To provide the necessary information a simple arrangement of hot and cold probes was set up, with a galvanometer to measure the potential. This apparatus was arranged so that the variables involved, such as probe loading, hot-probe temperature, probe size and shape, probe material and external circuit resistance, could readily be altered. The results obtained, some of which are detailed below, enabled a prototype instrument to be designed which has since been used in extensive laboratory and some industrial tests.

The tests described below were carried out with a series of standard test-pieces of known coating thickness. Calibration curves, similar to that of Fig. 5, showing galvanometer reading *versus* deposit thickness could then be obtained under varying conditions.

It was established that a hot-probe temperature of about 50°C. was adequate for several types of sample although it would be quite practicable to increase this to 80 to 90°C. Such a hot-probe temperature gave rise to potentials of the order of 100 microvolts.

Systematic experiments with a series of coatings of varying thickness showed that there was no marked variation in the calibration curve for reasonable changes in the load applied to the probes. This load need be no greater than is necessary for satisfactory electrical contact. For hard coatings a load of about 2 lb. is satisfactory and for soft coatings such as zinc or cadmium it is best reduced to ½ lb. or less.

Experiments with various probes showed that a probe tip having a radius of about 0.015 in. is suitable.

It was noticeable that soft coatings, where the contact area was necessarily greater caused some cooling of the probe tip and a downward drift in the galvanometer reading. However, by increasing the thermal inertia of the probe tip and using sufficiently light loads this effect was largely overcome.

Variations in external circuit resistance showed no effect unless this resistance became very low and of the same order as the contact resistance.

Tests with the galvanometer replaced by an electronic amplifier and cathode-ray oscillograph indicated that a steady reading was reached in a very short time as indicated by the theoretical study.

Available information suggests that the presence of stress in nickel produces only small changes in its thermoelectric power. This is of importance since nickel electrodeposits may differ widely in the internal stress they contain, and means that thermoelectric thickness measurements are unlikely to be influenced much by such internal stresses. Little systematic work has been done to check this point, but it is of interest that no trend was apparent in measurements made of steel strips plated with 0.0012 in. of organic bright nickel which had been plastically deformed by bending to a range of curvatures giving rise to deformations between 0.5 and 9.5 per cent in the deposits. The unbent deposit had an internal stress of about 10,000 lb. per sq. in. and cracked on bending to strains exceeding about 3 per cent so that the specimens presumably exhibited a wide range of internal stresses in both nickel and steel.

That a thin layer of chromium was without effect on the readings was confirmed by stripping the chromium from one half of chromium-plated, buffed dull nickel deposits, about 0.001 in. thick, on steel. The specimens were traversed by the probe in a direction at right-angles to the boundary between stripped and unstripped areas, readings being taken at 1-cm. intervals. There was no discontinuity in the trend of readings on crossing from chromium-plated to chromium-free areas.

It was found in the course of the experimental work that ambient temperature affected the readings obtained and thereby changed the calibration curve. This was found to be due to stray electromotive forces from other parts of the circuit and could be eliminated by a suitable arrangement of contacts between dissimilar metals.

Weller and Hanyz[5] have suggested that the source of thermoelectric potential is the point of contact between the hot-probe and the work surface. The temperature at this point will vary according to the thermal conductivity of the work, and they maintain that coatings of different thicknesses on a given base will influence the net conductivity strongly enough to account for the observed effects.

One particular experiment seems to show that the mechanism they have proposed is incomplete. A set of specimens having various thicknesses of electrodeposited nickel on steel were tested in turn with nickel and steel probes. When the nickel probe was used, thin coatings gave rise to a

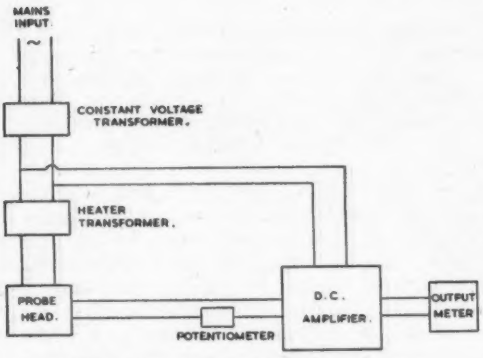


Fig. 2.—Block diagram of the thickness gauge.

large positive potential and thick coatlngs to a small positive potential. Such results will fit in with the theory put forward above, and also with that of Weller and Hanyz[5] if the effect of a thicker nickel coating is to cool the probe more and if at the same time there is a thermoelectric potential difference between the nickel of the probe and the nickel of the electrodeposit. However, when readings were taken with the steel probe, the thin coatings gave rise to a small negative potential and the thick coatings a large negative potential. Such results are not compatible with the explanation proposed by Weller and Hanyz[5], but are easily explained by assuming a large and approximately constant negative potential at the steel probe/nickel layer contact, and a varying potential at the nickel layer/basis metal interface as before.

The knowledge gained in the above experiments led to the design of a prototype equipment which is described in the following section.

PROTOTYPE THICKNESS GAUGE

Based on the exploratory work described above, a new model of the gauge was designed which was intended as the prototype of an instrument suitable for the measurement of coating thickness on a routine basis.

The instrument consists of six main components:

(i) The probe head which contains a spring loaded hot-probe, the heater winding for this probe, and the cold contacts.

(ii) A bench-type drill stand, modified to carry the probe head. A second spring-loading device allows a constant pressure to be maintained between both hot and cold probes and the work while a reading is taken.

(iii) A transformer supplying power to the heater winding in the probe head.

(iv) A potentiometer which can be used to back-off part of the signal from the probe head.

(v) A direct-current amplifier. Alternative amplifiers, one magnetic and one electronic, have been used with success.

(vi) A fairly robust milliammeter which indicates the output from the amplifier.

Fig. 2 shows a block diagram of the complete equipment. Fig. 3 is a cross-section of the probe head and Fig. 4 shows the gauge in use on a specimen.

Where appreciable fluctuation in the supply voltage is likely to occur a constant-voltage device would be desirable to stabilize the temperature of the hot-probe and maintain constant amplification conditions.

The backing-off potential is used in conjunction with adjustment of the sensitivity of the amplifier to ensure that the full-scale deflexion of the output meter can be used if required. Thus if no backing-off potential is used a change in coating thickness from 0.0002 to 0.001 in. may give a meter reading which goes from 50 to 70 meter scale divisions. If now the potential causing the deflexion from 0 to 50 divisions is backed-off the gain of the amplifier may be increased until the change in thickness gives readings covering the whole of the meter scale.

EXAMINATION OF COATINGS

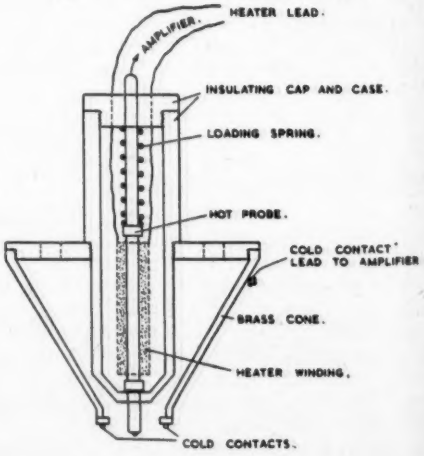
It is necessary to prepare calibration curves for each combination of coating and base of interest. Calibration curves appropriate to the instrument described were obtained for the following combinations:

(i) Two types of bright nickel on steel.

(ii) Dull nickel on steel.

(iii) A bright nickel on brass.

Fig. 3.—Cross-section of the probe head.



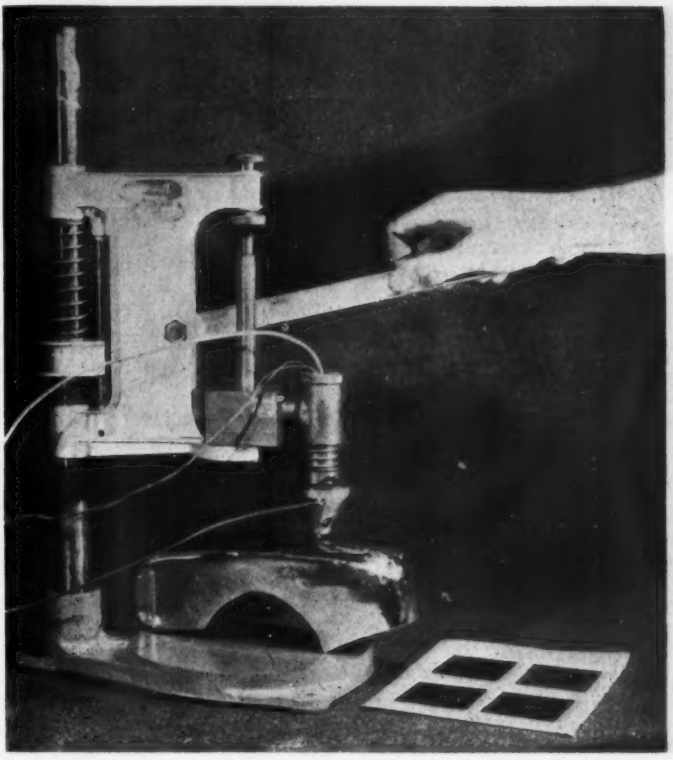


Fig. 4.—Showing the prototype gauge in use on a sample, and standard specimens for calibration.

(iv) Tin on steel.
(v) Zinc on steel.
(vi) Silver on nickel-silver alloy.
(vii) Cadmium on steel.
(viii) Cadmium on brass.
(ix) Nickel on aluminium.
(x) Tin-bronze on steel.

Calibration test-pieces were prepared in the form of panels 6-in. square and about 0.050 in. thick each bearing a deposit of a thickness in the range of interest. The central 2-in. square from each panel, on which the deposit thickness was expected to be substantially uniform, was reserved for examination by the thermoelectric gauge. The pieces whose edges were adjacent to this square were mounted for microscopic thickness measurement. Precautions were taken to avoid as far as possible errors arising as a result of the mounting or polishing techniques used. To determine the mean thickness of deposit on a test-piece some 40 microscopic readings were taken on the pieces adjoining the four edges of each 2-in. square and their mean value calculated together with their standard deviation. Standard deviations amounting to about 10 per cent of the coating thickness were found in most cases, although on the thin coatings, say 0.0002 in. thick, they were larger, about 20 per cent. It was concluded that the thickness of the supposedly

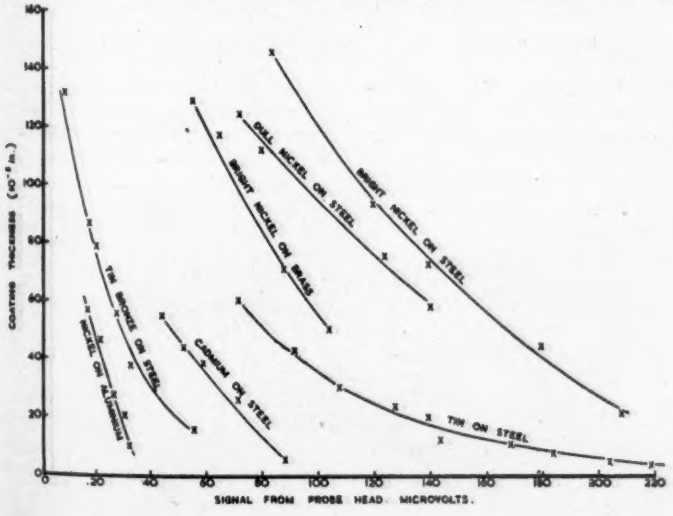


Fig. 5.—Calibration curves for various coatings.

Non-Destructive Thickness Gauge
(*continued from previous page*)

uniform coatings in fact varied from point to point over their area to an extent indicated by the standard deviation figures.

When the thermoelectric probe is used there will be instrumental errors arising at the probe contacts and through the circuits. To these must be added the error arising from the variation in coating thickness over the two-inch square test piece referred to above.

Some indication of the purely instrumental error was found as follows. Sets of 20 readings taken with the probe applied repeatedly to the same point of test pieces, gave a standard deviation of approximately 10 per cent of the coating thickness at all values of this thickness.

Thus the total standard deviations of readings taken at random on the test squares were about 15 per cent for coatings greater than 0.0005 in. and up to about 25 per cent for coatings of the order 0.0002 in. thick. Calibration curves could now be drawn relating the mean thickness over the test-piece area, as determined microscopically to the mean of an appropriate number of readings taken at random on the test piece using the thermoelectric probe.

Calibration curves prepared in this manner for a number of the coatings listed above are plotted in Fig. 5 and show the relative magnitude of the thermoelectric effects for the various combinations of coating and base. Obviously it is desirable in cases such as tin-bronze on steel and nickel on aluminium to back off any unwanted potential and to increase the amplifier gain thereby opening the scale.

With calibration curves drawn in this way, the error involved in determining the thickness of deposit from a single reading at a point on a sample is the instrumental error alone, represented by a standard deviation of 10 per cent of the thickness.

This figure for instrumental error is appropriate for most of the coatings indicated in Fig. 5; it is only where heavy cooling of the probe tip may occur, *e.g.*, with cadmium on steel, that additional errors may come in unless carefully controlled light loads are employed.

Further development of the instrument is now being undertaken on the basis of experience in the Association's laboratories and in collaboration with several member companies, and it is hoped that versions of the gauge will be commercially available in the near future.

Acknowledgements

The author wishes to thank the Director and Council of The British Non-Ferrous Metals Research Association for permission to publish this paper. He also wishes to thank Dr. G. L. J. Bailey for valuable help and discussion throughout this work.

References

(1) Brenner A. and Kellog, E. "A New Method for Magnetic Measurement of the Thickness of Composite Copper and Nickel Coatings on Steel." *J. Res. U.S. Nat. Bur. Standards*, 1948, 40(4) p. 295.
(2) Brenner, A. and Garcia-Rivera, J "An Electronic Thickness Gauge," *Plating*, 1953, Nov., 40 (11), p. 1238.
(3) Erwin, W. S. and Rassweiler, G. M., "Ultrasonic Resonance Applied to Non-Destructive Testing." *Rev. Sci. Instruments*, 1947, 18 (10), p. 750.
(4) Behr, F. A. "A New X-ray Gauge Checks Tinplate Thickness." *Non-Destructive Testing*, 1953, July, p. 33.
(5) Weller, E. F. and Hanyz, E. A. "A Thermoelectric Comparator." *Iron Age*, 1954, 4th March, 173 (9), p. 162.
(6) Bowden, F. P. and Tabor, D. "The Friction and Lubrication of Solids." Book, Oxford University Press, 1950.

SPRAYED METAL COATINGS

Publication of New British Standard

Prepared under the supervision of the Chemical Engineering Industry Standards Committee British Standard 2569 : 1955 has now been published in two parts, Part 1 under the title of " Protection of Iron and Steel Against Atmospheric Corrosion " and Part 2 " Protection of Iron and Steel by Aluminium Against Corrosion at Temperatures Between 120 and 950°C."

Part 1 considers the molten metal pistol, the powder pistol and the wire pistol processes and the protective metals detailed are aluminium (to B.S.1473-5) and zinc (to B.S.220).

Part 2 deals with the powder pistol and the wire pistol processes, the protecting materials being aluminium (to B.S.1473-5), and aluminium alloy (Cd 0.5 to 0.75 per cent and total impurities not more than 1 per cent).

Corrosion by Synthetic Detergents

It is well known that some of the early synthetic household detergents corroded aluminium, and a paper relating to this problem and the use of silicates as corrosion inhibitors is published in the April 1955 issue of the A.S.T.M. Bulletin. The authors, R. Getty, N. W. McCready and W. Stericker, conclude that while the silicate content of most popular detergents now on the market is sufficient to prevent the corrosion of aluminium, an increase would be desirable to reduce the corrosion of zinc and its alloys. Increased silicate content would also reduce staining on brass and nickel silver. Copper is unaffected by detergent solutions under normal washing conditions, but it may cause electrolytic corrosion when used with less resistant metals. Silicated detergents also reduce loss of gloss on enamels.

The Application of RUBBER and PLASTICS to the Metal Finishing Industry

Abstracted from a Paper presented to a meeting of the Midland Branch of the Institute of Metal Finishing held in Birmingham on February 1, 1955.

By E. W. MULCAHY

RUBBER

Introduction

RUBBER, in the vulcanized condition, can be soft or hard, and resemblance to steel is observed in the fact that in the pure state, rubber possesses a low tensile characteristic, but a high elongation. After suitably alloying, the tensile factor rises, but the elongation falls; (the latter being almost entirely eliminated in some grades). When heated, a hard condition is reached, in which there is little, if any, flexibility, the rubber having been converted to vulcanite, (a material which is highly resistant to chemicals but lacking in resistance to abrasion). With modern methods however, a variety of conditions can be produced by adjusting the variables, so yielding any degree of softness or rigidity that may be necessary, even combining hardness with good abrasive resistance when desired, or a fully vulcanized material which has reasonably good elongation.

Where materials of construction for tank linings etc., are concerned, the most important quality desired in the chemical and metallurgical industries is resistance to acid solutions, where concentrations and temperatures are within certain limits. An equally essential feature is sound electrical insulating properties.

As a protective lining or covering for metals, rubber can function by protecting them against chemical attack, and in its resilient form, it is an excellent protection against abrasive wear.

Applications of Hard and Soft Rubber

From the point of view of chemical resistance, ebonite or hard rubber is slightly superior to soft rubber, and its insulating properties are better than most compounded soft rubbers (with the exception of those where the rubber content is high, and relatively free from pigment fillers).

This flexible hard rubber is to be preferred, as a lining for steel tanks, where the temperature of the liquor is in excess of 60°C, provided its flexible properties are equal to the thermal expansion of the base metal. It is also preferred when handling delicately balanced solutions, such as bright nickel, etc.

With hard-rubber-lined steel tanks, (although often worked at temperatures of approximately 100°C), a certain amount of softening begins to take place at approximately 70°C. This is not a disadvantage under working conditions, owing to the extraordinary adhesion of the material to the base metal.

Soft rubbers can be used at high temperatures, but the adhesion to the base metal is not so sound and there is a possibility of blistering, although from the point of view of expansion due to temperature fluctuations, soft rubber is very accommodating. Where hard rubber linings are concerned, in the event of mechanical damage, it is not possible to provide a really satisfactory and permanent repair. Soft rubber need not be ruled out entirely for solutions such as bright

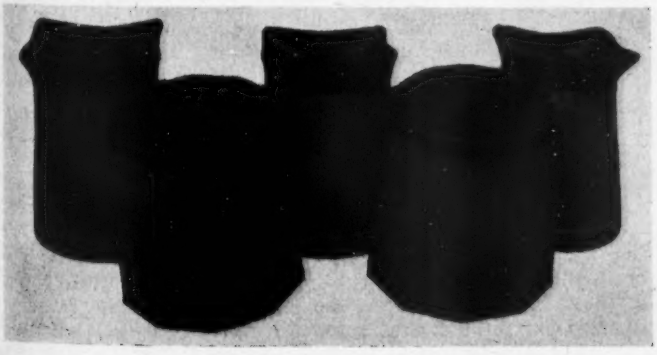


Fig. 1.—An assembly of electroplating barrels lined with rubber, with high insulating properties and sufficiently resilient to withstand severe abrasive wear.

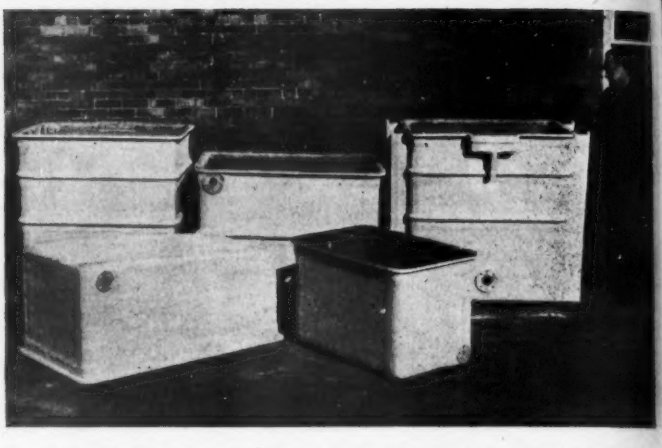


Fig. 2.—A collection of tanks fabricated in Fibreglass reinforced plastic.

nickel and there are instances where it is well worth considering, for example, the lining of vats which are difficult to move, or timber or concrete vats.

For the lining of pickling tanks, (whether steel or concrete), soft rubber is generally preferred, but it is an additional advantage to provide a protective lining of acid-resisting brickwork.

With the protective brick lining and depending upon the thickness (normally a maximum of 9 in.) temperatures up to 100°C can be satisfactorily accommodated.

Site Lining

It was basically for the use of chloride solutions that the development of site lining came about, and by 1927-28 it was quite common in Britain to see tanks of brick, timber and concrete, of almost any size, lined with acid-resisting unvulcanized soft rubber. The rubbers used for site lining are usually self-vulcanizing. Some of the author's experiences of site lining with soft rubber were associated with electro-chemical processes. One example (which was a highly successful venture), concerned a number of vats constructed of Staffs. blue bricks, cement screeded internally, which were lined for the heavy deposition of copper from a sulphate solution, on to rotating photogravure printing cylinders. The battery of vats were interlinked through a circulating and filtering system, the whole of which was entirely rubber lined. The current density of these vats was such, that more often than not, they were operating at temperatures approximately 120°F.

Jointing

It is possible to achieve satisfactory jointing of the rubber lining by the use of special types of jointing seams, by lapping the chamfered edge of one sheet on to the other, after the contact surfaces have been satisfactorily cement coated.

Present practice is the welding of the joints after lapping. This is effected by the application of a hot iron, which when applied to the rubber in the unvulcanized form, welds the two edges into a completely homogeneous joint.

Surface Preparation

To ensure satisfactory tank and vessel linings, the question of the fabrication of tanks, and the preparation of the surfaces is extremely important.

To simplify and ensure satisfactory results, "a steel tank should be fabricated to the rubber-liners' specification. The welds must be cleanly made, and in some cases it may be necessary to grind them smooth, where an irregular or porous weld has been made."

It is advisable that angle flanges and projecting fittings be provided with a radius at their intersections.

On completion of these preparations, the tank surfaces should be shot blasted, and the process of rubber lining carried out immediately after this latter operation, to ensure sound adhesion.

To be certain that there is no possibility of moisture present on the surface *or in the metal*, it may be advisable to submit the tank itself to steam heating treatment in a vulcanizing vessel before shotblasting.

As a measure of precaution, rubber linings are normally subjected to a high-frequency spark test after completion of lining, as a means to detect flaws in the sheeting or defects in the jointing.

Solid Rubber Constructions

Apart from the application of rubber as a protective lining in the metal-finishing industry, there are also many applications where equipment is fabricated entirely of rubber in its various forms *e.g.*, solid ebonite pipes, flanged or screwed and socketed, valves, cocks, acid-resisting buckets, pumps, flexible acid-resisting hoses, rubber aprons and various other commodities.

PLASTICS

Polyvinylchloride (P.V.C.)

One of the first and better known of the synthetic resin plastics is P.V.C. Its use has become well established and has greatly extended the application of plastic materials for the

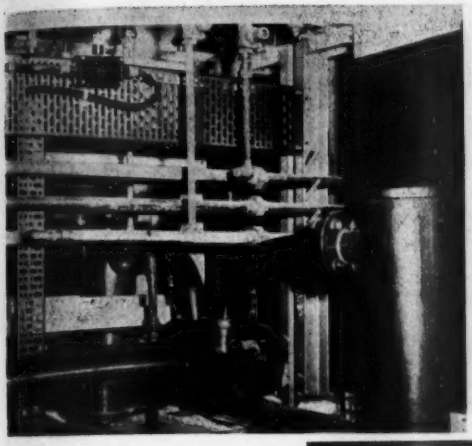


Fig. 3 (above).—An assembly of 3-in. and 6-in. P.V.C. piping, both flanged and spigotted, part of a processing and circulating system for handling corrosive chemicals.

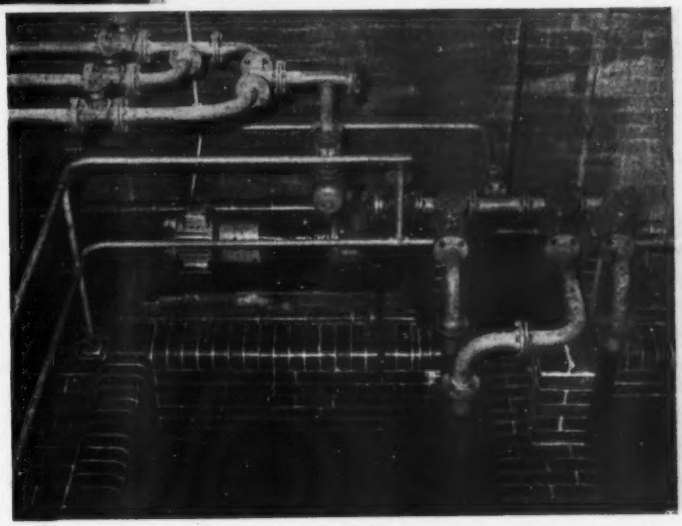


Fig. 4 (right).—An assembly of rubber-lined steel tubing and valves for handling sulphuric-acid pickling solutions.

protective covering and fabrication of tanks, pipes and other chemical plant components.

One of its most outstanding properties is its resistance at moderate temperatures to oxidizing solutions, such as nitric and chromic acid, etc. Also, as far as the metal-finishing industry is concerned, it has helped to solve the problem of accommodating bright-dipping solutions, at concentrations which are detrimental to rubber compounds and other plastic materials.

When heated to temperatures of approximately 110-130°C., P.V.C., in its rigid form can be shaped by any of the usual thermal plastic sheet techniques and can be formed into any desired shape on suitably prepared formers.

As a tank lining, it will adhere to steel surfaces and to a lesser degree, to smoothly screeded concrete surfaces. A certain amount of tank lining is carried out with this material in its plasticized form. While this is not so chemically resistant as the rigid material, it is simpler to manipulate and more easily adhered to surfaces. It can be welded in a similar manner to the welding of steel.

This material is now used extensively for the production of chemical pipelines and a recent experimental development is the lining of flanged steel tubing. One of its more popular applications is for the fabrication of fume ducting and hoods where its mechanical strength is such that it is self-supporting, and the joints between the independent lengths of ducting can be satisfactorily made with steel backing flanges, or by spigot jointing. One of the most familiar applications of P.V.C., in electroplating plants, is the covering of dipping racks and baskets.

Polythene

Polythene is a material which has very similar qualifications to P.V.C. It can be produced in a range of colours and is used extensively in all branches of industry. It differs from P.V.C., in as much as it has a distinct wax-like appearance and has a greater impact strength. The outstanding combination of its mechanical strength and chemical resistance, together with its ease of operation, makes polythene a valuable addition to industrial materials of construction.

Polythene has very high resistance to chemical attack, but like P.V.C., it is *NOT* advisable to use this material at temperatures in excess of 60°C.

It can be used for the fabrication of ducting, and for the manufacture of small portable items of equipment used for handling chemicals, and is used occasionally as a "loose" tank lining

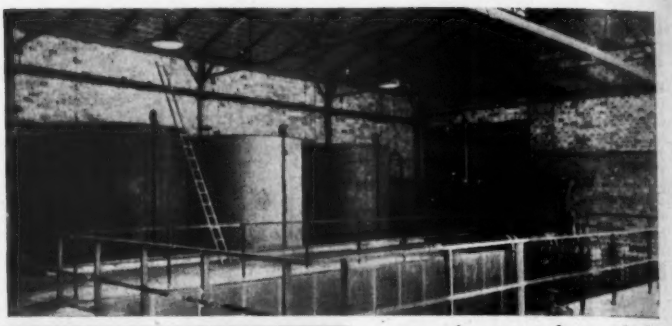


Fig. 5 (right).—In the foreground a reinforced-concrete pit lined with plasticized P.V.C. for receiving spent acid discharged from a continuous strip pickling line. In the background three rubber-lined mild-steel storage tanks for the storage and preheating of regenerated sulphuric-acid pickle liquor.

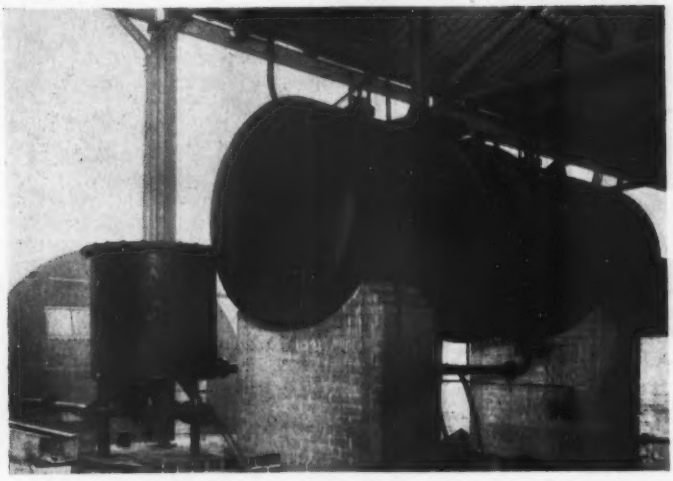


Fig. 6 (below). — A rubber-lined bulk storage tank for hydrochloric acid, with 100-gallon rubber-lined measuring vessel. Both tanks are fitted with level indicators, and all interconnecting valves and pipework are rubber lined.

because the physical properties of the material are such that it cannot be adhered to *any* surface. This material is strongly resistant to oxidizing solutions of normal operating strengths and as in the case of P.V.C., small vessels can be readily fabricated from sheet.

Although P.V.C., and polythene have established themselves as excellent materials for the fabrication of chemical plant, the same cannot be said of them as tank linings. A certain amount of success has been achieved with solutions at *normal* temperatures, but with fluctuating temperatures, even well below the stated maximum, linings have deformed or completely collapsed. Polythene is used extensively in industry for piping chemical solutions.

REINFORCED RESINOUS PLASTICS

Reinforced resin plastics have been used as constructional materials for chemical plant in industry for a good many years, and articles of equipment manufactured from these materials are found in almost every branch of chemical industry. These materials are composed of resins compounded with inert fibrous material, and the plant can be manufactured by moulding to practically any shape.

A relative newcomer to the wide range of acid-resisting materials that is available to the chemical industry is Fibreglass reinforced plastic (F.R.P.) with high specific strength, ease of forming to complex shape and excellent resistance to chemical and heat conditions depending upon the type of resins used in the moulding of the material. Thermosetting resins are used on account of the stability at high temperatures. The types of resins used normally include polyesters, phenolics, furanes, silicones, etc.

The mechanical properties of the material depend chiefly on the amount of glass present and its arrangement. Apart from its exceptional resistance to acids with phenolic and furane resins, it is reasonably resistant to alkalis, and in view of the fact that glass is normally attacked by alkaline solutions, it is important in construction of the resinous laminates, that the glass is well protected by the resin.

This material can cover precisely the same range of applications as any of the aforementioned plastics, and because of its extraordinary mechanical strength, equipment can be manufactured with extremely thin walls which will stand up to appreciably heavy shock without fracture. Piping is now being manufactured from F.R.P. and can be very simply jointed on site with resinous solvents or with loose couplings.

The material is also used for the fabrication of plating baths and its chemical resistance and insulating properties are such that it can cover a wide range of the requirements of the electroplating industry.

The NATURE and SIGNIFICANCE of MILL ADDITIONS in Vitreous Enamelling

by J. J. GUY, B.Sc., A.C.G.I., A.M.I.Chem.E.

(A Paper presented to a meeting of the Southern Section of the Institute of Vitreous Enamellers.)

THE number of materials added to enamels at the mill has increased very much in recent years with the advent of newer types of enamel and newer requirements. There are, however, fundamental reasons why particular materials should be used for particular purposes, and it is the aim of this paper to discuss these fundamentals.

For purposes of classification mill additions fall into five groups: 1. Clays and suspending agents. 2. Electrolytes or clay modifiers. 3. Oxides and opacifiers. 4. Water. 5. Chemicals added for other specific purposes.

Undoubtedly the clays and electrolytes are the most important, since without them a usable slip could not be prepared, and as they are inseparable in practice they can be dealt with together.

CLAYS. Clays are aluminium silicates produced by the weathering of felspars, and the ball clays which are used in enamelling have been carried by water to the places where they are found, and therefore consist of very fine particles, of the order of 1/1,000 mm. diameter. The basic clay material is kaolinite having the formula: $Al_2O_3.2SiO_2.2H_2O$. This has a melting point above 1,700° C., and is therefore a refractory from the enameller's point of view. In most clays there is some organic material present, and there may be other impurities, such as mica, quartz, felspar, and iron compounds. Bentonites are a different kind of clay material, having a different composition, structure and properties, and consisting of finer particles than clay.

The organic matter in clays is important in that it is primarily responsible for the bubble structure in the fired enamel. For this reason clays which are low in organic matter, such as the yellow clays, are more suitable for the production of bright colours.

ELECTROLYTES. Electrolytes or simple salts when dissolved in water split up into electrically charged ions, the metal part of the salt being positive, and the non-metallic part negative. Thus, for example, magnesium-sulphate solution contains positive magnesium ions and negative sulphate ions. The alkali metals, lithium, sodium, and potassium carry one charge, the alkaline earths, magnesium, calcium and barium, carry two, and some others such as aluminium, carry three.

Acids and alkalis are electrolytes, the former giving positive hydrogen ions, and the latter negative hydroxyl ions.

Turning now to their effects in the mill, one can begin by considering the milling of a frit and water alone. Such a milling takes a long time to grind, there is a large proportion of unground frit, and the resulting slip settles quickly to a hard mass on the bottom of the container.

If a similar milling is made, but with clay as an extra addition, the same is likely to occur, except that the fine clay particles will remain in suspension.

If to each of these millings is added a small quantity of one of the common electrolytes a significant change occurs. Each slip will become more viscous and acquire a "set," and each will settle more slowly to give a bulky, soft sediment. These changes will be more pronounced in the clay milling.

These effects are due to the presence of fine, or colloidal, particles, in one case of overground frit, and in the other, of clay. Very fine particles have a large surface area per unit weight: for example, 1 lb. of clay has a surface area of about three acres. This means that a great deal of adsorption of ions can take place on this surface, giving rise to substantial forces between the particles. In fact, clays can be used as ion-exchange materials in water softening, since they will adsorb calcium ions from hard water and replace them with sodium ions, if they have previously been saturated with these.

Colloidal clay and frit particles when suspended

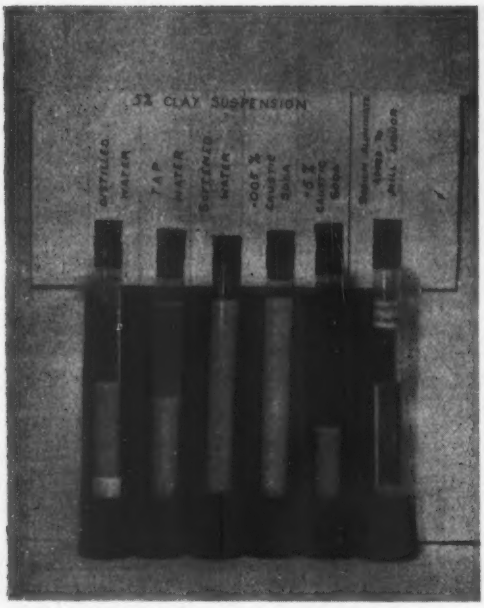


Fig. 1.—Experiments showing varying flocculations.

in water acquire a negative charge round them, probably due to the adsorption of hydroxyl ions. In the absence of other ions, the clay particles in this condition will repel one another. This is known as a deflocculated state.

The addition of electrolytes has two effects. Firstly, the positive metal ions link the negative clay particles together to form a rather loosely knit structure which supports the larger frit particles. This effect is called flocculation or coagulation of the clay.

This coagulated structure requires a certain amount of force to shear it, hence the "set" of flocculated clay suspensions. The set is, of course, essential for dipping, for preventing sprayed enamel from running off vertical surfaces, and for preventing the coarser particles of the slip from settling.

On the other hand, excessive set will prevent a sprayed enamel from flowing adequately, and will result in an "orange-peel" surface, and in dipping enamels will require an excessive amount of water to be used in the slip, causing very short draining and water marking.

Furthermore, the flocculated clay structure persists in the dried biscuit stage, and helps to give hardness to the biscuit.

The second effect arising from electrolyte addition arises from the fact that most metal ions gather round themselves a number of water molecules, *i.e.*, they become hydrated. When this happens less free water is left in the body of the slip which thus becomes more viscous.

As would be expected, the greater the charge on the ion, the greater is its coagulating power. Thus, while sodium, potassium, and ammonium salts have only a mild setting-up action, calcium barium, and magnesium are very much more powerful. These divalent ions are also hydrated to a greater extent than are the monovalent ions, and therefore reduce the mobility of the slip more markedly.

It must also be remembered that when salts of calcium, magnesium, barium and aluminium are added to the mill they react with the mill liquor to form insoluble precipitates of *e.g.*, calcium hydroxide or aluminium hydroxide. This has the result of removing some of the metal ions which are thereby prevented from coagulating the clay. At the same time the precipitate adds to the amount of colloidal matter present, and is equivalent to an extra clay addition. Some of these colloidal precipitates carry a positive charge, and can help to link the clay particles together. This is particularly so in the case of aluminium hydroxide, and this accounts for the great effectiveness of sodium aluminate as a setting up agent since it gives aluminium hydroxide when dissolved in water (Fig. 1).

The effect of alkalis upon clays is particularly important. A small addition of alkali first of all deflocculates a clay, and only when a larger amount has been added does the usual flocculation occur. The mechanism of this is not entirely clear but it seems that the initial deflocculation is due to the mobile negative hydroxyl ions which repel the negative clay particles and keep them apart. In this condition they do not impart the semi-rigidity which is needed in a slip, and the frit particles rapidly settle out.

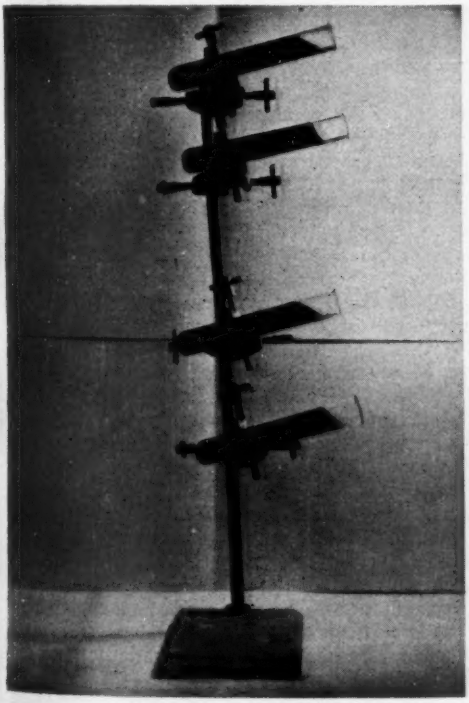
Fig. 1 shows suspensions of clay in water and in alkaline solutions after a 30-minute settling period. In the dilute caustic soda the clay particles are dispersed and have not settled markedly, while in the tap water and strong alkali solution the clay particles have become bigger by coagulation and settle more rapidly. The 0.005 per cent solution represents approximately the point of maximum deflocculation.

The degree of alkalinity, or *p*H value, at which this deflocculation is a maximum, will vary with the type of clay, *e.g.*, the Dorset clays are less susceptible to this deflocculation than are the Devon clays, but it usually occurs at a weak alkalinity of about *p*H = 7 to 9. For this reason weak alkalis, such as sodium pyrophosphate and sodium silicate will act as de-setting agents in enamel slips. These salts are particularly effective since they also precipitate any calcium or magnesium salts at the same time.

Where constant set is required in an enamel, as, for example in enamels for dipping, it is clearly important to keep the *p*H value of the slip constant. There are many substances, called buffer solutions, which will keep the *p*H value steady at any value required, and if, for example, one is chosen that will maintain the *p*H of the slip just above that at which deflocculation occurs, that slip will have a very steady set. Borax is one such substance, and for this reason is a useful addition to sheet-iron ground coats.

This action of alkalis explains the difference in ease of setting-up different types of enamel. When enamel is ground in the mill, alkaline soda and acidic boric oxide are dissolved from the frit, and the ratio of these two oxides, which determines the *p*H of the mill liquor, will differ according to the type of frit. In the case of the A.R. titanium whites, this ratio is one which puts the *p*H in the region of maximum deflocculation, hence the difficulty experienced in setting up this type of frit. Borax would not be a suitable addition in this case, since it gives off a great deal of steam during fusing, and causes tearing in cover coats. Instead, it is usual to increase the alkalinity to a point above that of deflocculation by the addition of such salts as sodium aluminate and potassium or sodium carbonate.

Fig. 2.—Experiment demonstrating thixotropy.



In this connexion it is important to note that bentonite is relatively inert to the action of electrolytes, and especially to that of alkalis, which do not cause a bentonite slip to deflocculate. For this reason bentonite is a useful addition to prevent loss of set upon ageing. Another interesting feature of bentonite slips is that they have, to a marked degree, the property of thixotropy. This is the increase in yield value or set of the slip when it is stationary, and while clay exhibits this property, bentonite has it to a much greater extent.

A thixotropic material when allowed to stand for a few seconds acquires a much higher rigidity than when it has just been agitated, hence a thixotropic slip will not be so liable to double run from a plate dipped into it or sprayed with it, and it will have less tendency to settle out when left standing.

Too great a thixotropy makes a slip difficult to handle, and $\frac{1}{2}$ per cent is the usual limit to the amount of bentonite used.

This effect is demonstrated in Fig. 2, where the upper pair of test-tubes contain a ground coat slip milled with 5 per cent clay, $\frac{1}{2}$ per cent bentonite, $\frac{1}{4}$ per cent borax and $\frac{1}{16}$ per cent sodium nitrite, and the lower pair contain the same frit and electrolyte but with 6 per cent clay alone. The two slips are at the same density and give the same pick-up weight on a metal sheet dipped into them.

The upper test-tube of each pair has been inclined immediately after agitating the slip, while the lower tubes have been inclined after allowing to stand for 30 seconds.

The slope of the enamel surface is a measure of the yield value of the slip and it will be seen that the bentonite exhibits a marked increase in yield value upon standing.

It is noteworthy that divalent salts impart thixotropy to a slip to a greater extent than do monovalent salts, and if, for example, an enamel is set up with a magnesium salt it will remain in suspension better than if set up to the same extent by a sodium salt.

The effect on the consistency of the slip is only one aspect of the use of electrolytes. The enameller must also consider each salt from the point of view of its effect on the fired enamel, which it may affect by its reaction with the metal base, the atmosphere, or the frit.

The iron base, whether sheet or cast, is very prone to rusting, which is an electrochemical process taking place in the presence of oxygen. Sodium nitrite is a very strong deoxidant or reducing agent, absorbing oxygen to form sodium nitrate. As a consequence it is a very useful addition to any sheet-iron ground coat or cast-iron enamel in minimizing the effect of rust-

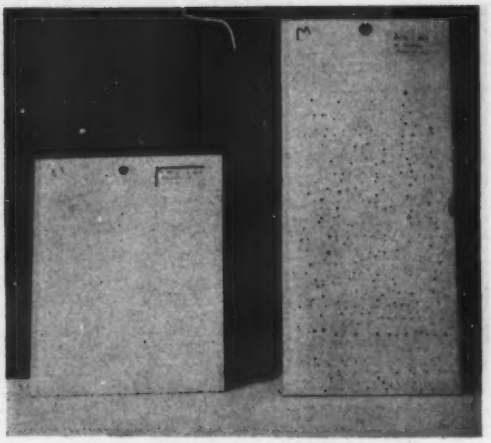


Fig. 3.—Effect of chloride additions.

spotting. Furthermore it melts at 270°C. and its fluidity during the initial stages of fusing is a great help in reducing the tearing of the biscuit. It may be worth mentioning here that sodium nitrite is toxic; it should also be kept in a closed container to exclude oxygen.

Broadly speaking, all alkaline substances will inhibit rusting.

All chlorides have a strongly corrosive effect on iron, and if used in ground coats and direct-on enamels are very likely to cause severe copper-heading. Fig. 3 shows an A.R. white enamel applied directly to sheet iron, the left-hand sample being milled with sodium nitrite and sodium aluminate, and the right-hand sample with potassium chloride and sodium aluminate.

Industrial and furnace atmospheres can have a very marked effect on enamel by producing scumming and other similar faults, and it has been proved that sulphur dioxide is the principal cause of these faults. Sulphur dioxide is an acid gas and reacts with alkalis to form sulphites, and it is almost certainly the soluble sulphites of sodium and potassium which cause scumming-type faults. Any reduction in the alkalinity of the mill liquor will therefore be helpful in preventing scumming. As would be expected from these considerations, sodium aluminate, and to a lesser extent sodium nitrite and the alkali carbonates all increase the likelihood of scumming faults.

Insoluble sulphites, such as those of calcium and barium do not appear to cause scumming, and the use of calcium and barium salts in the mill has been found beneficial. Zinc oxide has also been successful in reducing scumming.

An interesting instance of these effects occurred recently at the author's works where an unusual fault occurred on sheet-iron titanium cover coat. It took the form of a rucking or folding of the surface (for which the term, "pigskinning" was coined) together with some shorelining, which appeared on work left in biscuit for more than an hour or so before firing. It appeared on various makes of cover coat, and numerous experiments showed it to be associated with the shop atmosphere. The fault could be simulated by spraying the biscuit with sodium sulphite, but not sodium sulphate, and it was found that the percentage of sulphur in the freshly sprayed biscuit was $\frac{1}{500}$ and that in the affected biscuit was $\frac{1}{30}$. The mill formula contained $\frac{1}{4}$ per cent sodium aluminate, $\frac{1}{8}$ per cent sodium nitrite, and $\frac{1}{8}$ per cent potassium chloride, and had a *p*H value above 10. By replacing the sodium aluminate and sodium nitrite by $\frac{1}{8}$ per cent of barium chloride the trouble disappeared completely.

As far as their effect on the fired enamel is concerned it is broadly true to say that in excess all electrolytes are detrimental. All materials which evolve gas upon heating, such as the carbonates, will increase the bubble structure of the enamel and will reduce the gloss, acid resistance, and scratch resistance of cover coats. In ground coats increased bubble structure is an advantage, since it provides a reservoir for the gases which might otherwise cause fishscaling, and increases the resilience of the enamel. An addition to the ground-coat mill of calcium or barium carbonate will reduce fishscaling tendencies.

An addition at the mill of barium or calcium carbonate of the order of 2 per cent is sufficient to prevent the incidence of fishscaling even on metals which are known to be liable to give rise to this defect.

Chlorides, particularly those of sodium and potassium will increase the gloss and whiteness of an enamel, although they have a tendency to cause "popping off" of the cover coat.

Ammonium salts are popular additions since they are completely decomposed during fusing, and can leave nothing which is likely to be of detriment to the fired enamel, but they have the disadvantage that they have only a slight setting-up action, particularly on the modern titanium enamels.

Urea has become a very popular addition in recent years since it reduces tearing in cover coats. It should always be added to the slip as a solution just before use, since it decomposes readily, particularly in the presence of sodium nitrite.

Various lithium salts, such as the cobaltate and titanate have been suggested as useful mill additions to soften enamels and improve adherence, but personal experience of them has been that in relation to their cost they are ineffective, when compared with the same additions to the smelt.

(*continued in page* 176)

NUMBER TWO

METAL FINISHING RESEARCH
A Survey of its Organization, Existing Facilities and Current Work

The Work of The B.I.S.R.A. Coatings Research Laboratory at Sketty Hall, Swansea

by S. S. CARLISLE, M.Sc., A.M.I.E.E.*

Introduction

THE policy of the British Iron and Steel Research Association has been to set up laboratories in different centres of the steel industry so as to serve both local firms and the industry as a whole. South Wales was an obvious choice for one of these laboratories, being one of the most important steel-producing areas. Since this area is now the main wing of the flat rolling, tinning and galvanizing industry it was particularly appropriate that the laboratories at Sketty Hall should concentrate their attention on coatings and coating processes.

Since 1932 a group led by Mr. D. Luther Phillips had been working in the metallurgy department of Swansea University College under the direction of Professor Edwards. This group was set up by the South Wales Siemens Steel Research Committee and the Welsh Plate and Sheet Manufacturers' Association. Their work included the study of the effects of cold rolling and heat treatment on the properties of mild-steel sheet, the effect of composition and processing on the corrodibility of steel, and the effect of special addition elements on the strain-ageing of low-carbon steels, as well as investigation of works problems concerned with coatings.

On the formation of B.I.S.R.A. in 1945 this research group became part of the Association and came under the direction of the Mechanical Working Division, which now also has laboratories at Sheffield to carry out research into rolling and sheet-metal-working problems. There is thus provided the essential close linkage between coatings and the steel base qualities. The research group in the College soon outgrew its accommodation and in 1946 it took over the historic 40-roomed mansion in Singleton Park known as Sketty Hall. After suitable conversion the laboratories were officially opened in July 1947. Fig 1 shows Sketty Hall as it now is.

The research team has grown to about 30. Mr. Luther Phillips, who built up the laboratory and directed its work, retired in February 1954. He was succeeded by Mr. S. S. Carlisle. Senior investigators Dr. M. L. Hughes, Dr. F. W. Salt, Mr. W. Bullough and Mr. T. C. Toye form the core of the research staff.

The programme of research is primarily concerned with the surface treatment of steel and particularly with the application of metal and other inorganic coatings to steel, including the study of the coating and its behaviour, development of coating processes and study of the properties of the steel which influence the coating. More specifically the present and future activities of the laboratory will be concerned with—

(a) Development of high-speed continuous strip-coating processes to keep pace with modern methods of producing and handling strip.

(b) Improvement in methods of coating to give better protection with thinner coatings and so economize in coating materials and enhance the ability of the coated strip to withstand fabrication as occasioned by deep drawing and forming.

(c) Development of new coatings.

(d) Development of improved methods of inspection to operate at high strip speeds.

The work of the laboratory is best described by reference to some of the recently completed and current projects in the laboratory.

Iron-Zinc Alloy Coating

A method has been developed for joint electrodeposition of iron and zinc on steel sheet to form an alloy coating whose composition depends on the conditions of deposition and the composition of the coating bath[1]. Alloys have been deposited with zinc contents varying from 3 to 90 per cent. It has been observed that a coating containing about 6 per cent zinc is nearly as reflective as a perfect mirror. It adheres well to the steel sheet and has a smoothing effect, that

* Head of the South Wales Laboratories, B.I.S.R.A.

Fig. 1.—Sketty Hall, Swansea.

is, the coating is deposited first in the hollows of the steel, so that the mirror surface is obtained without buffing on an etched plate. The coatings can be deposited at the rate of about 0.0001 in. per minute, and have a hardness of 560 D.P.N. The alloy surface does not tarnish indoors but does not resist corrosion sufficiently well to be used outdoors. An alloy containing 63 per cent of zinc has a lustrous surface and a hardness of about 300 D.P.N. and it can be deposited at about the same rate as the 6 per cent alloy. Preliminary tests suggest that it will resist outdoor corrosion well. A coating of this alloy deposited on a steel sheet has been buffed to a mirror brightness and chromium-plated. The resultant finish is shown in Fig. 2.

Several specimens of each of the alloy coatings in a range 10 to 90 per cent zinc have been prepared and are now being subjected to long-term atmospheric exposure tests. Tests are also in progress to establish the corrosion resistance of a chromium-plated specimen using a 60 per cent iron-zinc alloy as an undercoating.

The application of this coating in the industry is being encouraged and one firm is now developing the process further for application to steel sheet as a base for painting.

Research in this field is being continued in the development of a process for deposition of an iron-tin alloy.

Corrosion of Tinplate by Fruit Packs

The shelf life of some canned fruits is undesirably short, it being found that, after a period of stortage the can swells due to the evolution of hydrogen. The corrosion process which causes this is normally quite harmless but a swollen can is almost invariably discarded because it causes suspicion of bacteriological action in the can which could be toxic. A joint investigation is therefore being carried out in co-operation with the Metal Box Co. Ltd. and the Fruit and Vegetable Canning Research Association in which B.I.S.R.A. has so far been studying the mechanism of the corrosion, so that suggestions might be made for means of prolonging the shelf life. Particular attention has been given to lacquered cans containing such fruits as Victoria plums, raspberries and yellow plums. Lacquering in these instances has been found necessary to prevent discolouration of the fruit by dissolved tin. So far it has been found that the colouring constituent in Victoria plums and raspberries, known as chrysanthemin, can act as a depolarizer and thus facilitate the corrosion of tin in anaerobic citric or malic acid. In a lacquered can the attack on the tin is concentrated at breaks in the lacquer so that the tin is quickly penetrated and iron exposed. Corrosion of the iron by the fruit juice acid results in hydrogen evolution and consequent swelling of the can. This theory explains much of the observed phenomena and a search is now being made for possible inhibitors of the corrosion of the iron.

In the course of this work a radioactive isotope method has been proposed for determination of the area of iron exposed due to porosity in tinplate and this method is being developed in conjunction with the Atomic Energy Research Establishment at Harwell. The technique is to immerse the tinplate in a solution of cobalt salt containing some radioactive isotope, and since the cobalt is below iron but above tin in the electrochemical series, deposition of cobalt by chemical displacement occurs only on the iron exposed at the pores in the coating. When the treated plate is left in contact with a photographic film an autoradiograph is produced in which the darkened areas on the plate indicate the presence of radioactive cobalt that has been deposited at the pores. By

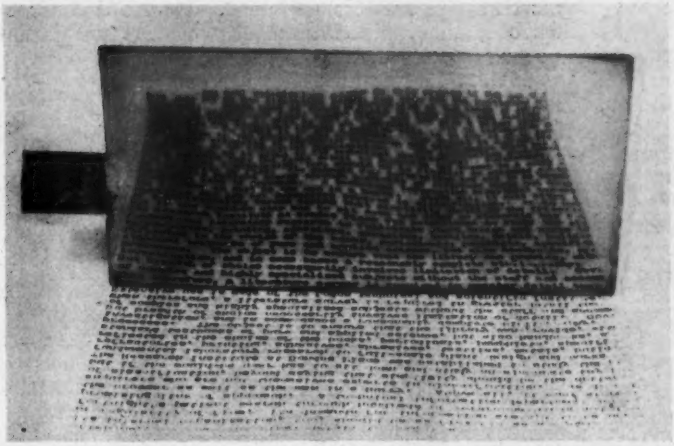


Fig. 2.—An iron-zinc alloy coating containing 63 per cent zinc.

measurement of the total radiation from a treated specimen with a Geiger-Müller counter the area of iron exposed can be determined by comparison of the counter reading with that from standard specimens.

Hot-Dip Aluminized Steel

A simple continuous hot-dip method of coating steel strip with aluminium has been developed in the laboratory[2]. Since aluminium coatings can withstand temperatures up to 700°C, aluminium-coated steel is suitable for use in many industrial processes that require temperatures too high for tin or zinc coatings. Aluminium is generally resistant to corrosion, and if body members of motor and railway vehicles can be coated with it they can be bonded to aluminium body sheet without placing dissimilar metals in contact. Thus a troublesome source of corrosion could be removed and at the same time protection is given against ordinary rusting. It has good resistance to atmospheric exposure and could serve well for building cladding because of the combination of the high reflectivity of the aluminium surface and the strength of the steel base.

Several difficulties have been encountered in the past in the development of the hot-dip method of aluminizing. These have been largely due to the hard and brittle layer of iron-aluminium alloy which is formed on the steel surface, which limits the deformation which the coated sheet will withstand. Also an oxide skin forms on the surface of the aluminium bath and some of this oxide is picked up by the immersed steel, so marring the surface. Various methods had been proposed for working with a molten flux blanket on the bath as in galvanizing, but none of these have proved entirely satisfactory. The difficulty caused by the oxidation of the ingoing strip was overcome in the B.I.S.R.A. method by careful preparation of the surface, after which a film of glycerol was applied. This avoided the use of a flux and enabled the strip to be passed into the aluminium bath through a protective box, which prevented the aluminium-oxide film reaching the strip. The burning of the glycerol on the surface of the aluminium discouraged oxidation of the aluminium surface and maintained the strip free from oxidation prior to immersion. The growth of the iron-aluminium alloy is retarded by addition of a small percentage of silicon to the aluminium bath.

This process was successfully worked on continuous strip up to 3 in. in width, and has the additional advantage that heavily cold-worked steel can be annealed as it is coated, which in many cases is a great convenience and economic advantage.

The process has been applied by one firm for aluminizing steel wire and further application of the process is largely dependent upon development of the market for aluminized steel.

Further study of the properties of aluminized steel has shown it to have a particular advantage in its scaling resistance. For example, it has been found that heating for up to 2,000 hours at a temperature of 700°C. shows negligible scale growth. There is little loss of lustre of the aluminium surface for temperatures up to 550°C.

Recovery of Zinc from Galvanizers' Dross

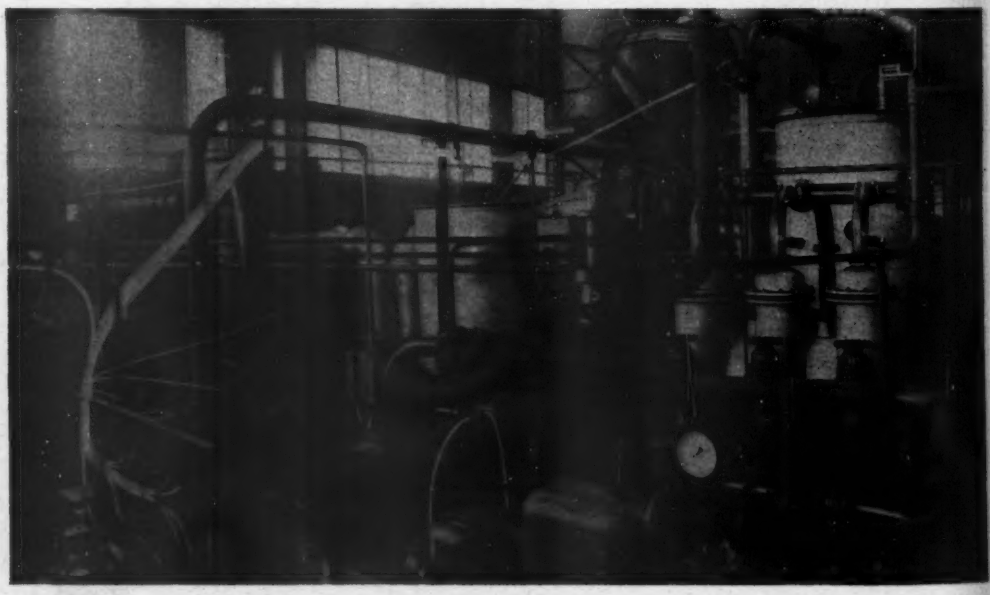
A few years ago the severe shortage of zinc was a strong incentive to attempt to save it. The large differential which existed in the market prices of zinc and dross also encouraged the investigation of means of reclaiming zinc from

dross. This metal sludge or dross which collects at the bottom of galvanizing pots can spoil the coating if it comes into contact with it, and consequently the dross is periodically removed from the pot. The dross contains about 97 per cent zinc and 3 per cent iron and is thus of considerable value. A high percentage of this zinc is present as free zinc and merely trapped in the dross, which is otherwise iron-zinc alloy. A novel method for recovery of a high percentage of the zinc from dross has been developed at Sketty Hall.

This process consists of adding the dross with some aluminium to a bath of lead and heating the whole melt to about 750°C. The iron combines with the aluminium and floats to the surface as an alloy, while the zinc dissolves in the lead. The iron aluminium compound is skimmed off and the zinc-lead solution is allowed to cool to a temperature at which the zinc crystallizes out on top of the molten lead. The zinc is then removed as a solid block and the lead can be used again. By this process it is possible to recover 95 lb. of pure zinc from each hundredweight of dross.

This method of recovery is comparatively cheap and simple and can be used in any works[3]. It is particularly suitable for operation on a small scale as might be required in a galvanizing works. The economic value of the process depends on the relative market values of zinc and dross which at the moment are favourable.

Fig. 3.—Pilot plant for the recovery of sulphuric acid from waste pickle liquor.



Recovery of Sulphuric Acid from Waste Pickle Liquor

A shortage of sulphuric acid a few years ago threatened the steel industry with serious difficulty in pickling sheet for tinning and galvanizing. Since then the increasing difficulty of disposing of the waste liquor and the tightening up of legislation relating to river pollution has made the development of a suitable process for recovery of acid from waste pickle liquor a matter of extreme urgency.

Some four years ago a method of producing sulphuric acid from waste pickle liquor by the autoxidation process was developed at Sketty Hall. This process assumed that ferrous sulphate monohydrate could be made available from the waste pickle liquor by evaporation and consequent precipitation of the monohydrate. After filtration the acid from the sludge can be returned to the pickling tanks and the monohydrate passed on for treatment by the acid recovery plant. Such a process is now being operated at the Trostre Works of the Steel Company of Wales Ltd.

The B.I.S.R.A. process for treatment of the monohydrate involves roasting the monohydrate to evolve the sulphur dioxide and sulphur trioxide, and after removal of the sulphur trioxide by washing, the sulphur dioxide is converted to

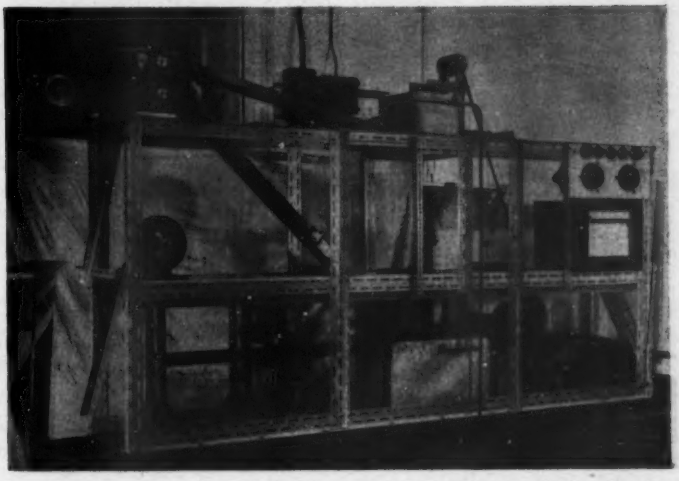


Fig. 4.—Experimental continuous hot-tinning line for 1-in. wide strip.

sulphuric acid by the autoxidation process. In this process the sulphur dioxide is mixed with air (oxygen) and passed in the form of very small bubbles up through water or dilute acid containing manganese sulphate, which acts as a catalyst in the oxidation of the sulphur dioxide. Having proved this process on a laboratory scale it was decided to design and erect a pilot plant to further develop the process on an industrial scale. A pilot plant to produce the equivalent of 1 ton of sulphuric acid per day in the form of weak acid has, in consequence, been built by Simon-Carves Ltd., at the Kings Dock Works of the Steel Company of Wales Ltd. This plant is shown in Fig. 5. The erection and operation of this plant is a joint venture involving the Steel Company of Wales Ltd., Simon-Carves Ltd., and B.I.S.R.A. The process carried out by this pilot plant is as follows:—

The ferrous sulphate monohydrate is roasted in a rotating stainless-steel retort, so giving off a gas containing sulphur dioxide and sulphur trioxide and leaving a residue of iron oxide which after, sintering, might be suitable for use in a blastfurnace. The furnace gas is then cooled and the dust and sulphur trioxide extracted by passing the gas up a packed wash tower, down which flows cold, dilute acid. The resulting hot, dusty and more concentrated acid is cooled, diluted and its dust allowed to settle before it is returned to the tower. The acid made in this process by the sulphur trioxide is tapped off and, after passing down a stripper to remove the dissolved sulphur dioxide, is delivered to the acid store tank.

The washed furnace gas containing sulphur dioxide and air from the tower is passed up through an absorber tower, down which flows sulphuric acid from the store tank, so that the sulphur dioxide in the gas is taken into solution by the acid. The resulting acid with sulphur dioxide in solution is fed into the diffusion tank in which the autoxidation process is carried out. In the bottom of this tank there is a system of ceramic porous tubes into which air is fed from a compressor unit so that air (oxygen) is fed into the bottom of the tank in the form of very small bubbles. A trace of manganese sulphate is added to the acid in the diffusion tank so as to catalyze the reaction between the oxygen and the sulphur dioxide to form sulphuric acid. The acid so made in the diffusion tank is then bled off to the store tanks when the strength has been built up to a suitable value.

This pilot plant has now been working on and off for trial purposes over a period of some three months, and although there are some problems to be solved in connexion with the design of a full-scale plant, it has become clear that the autoxidation process is quite a practical proposition for the making of sulphuric acid from sulphur dioxide and can be operated satisfactorily and economically on the scale required by steel works for recovery of acid from their waste pickle liquor. Trials are continuing on the pilot plant in order to produce necessary data to facilitate the design of a full scale plant.

Continuous Hot-Tinning of Steel Strip

A large part of the tinplate now produced in this country is by the electrodeposition process, and the popularity of this process is increasing since American practice has shown that coating weights of 16 ounces per basis box can be applied at speeds of 1,000 ft. per minute. The rapid development of this process has been largely due to it being the only means of providing

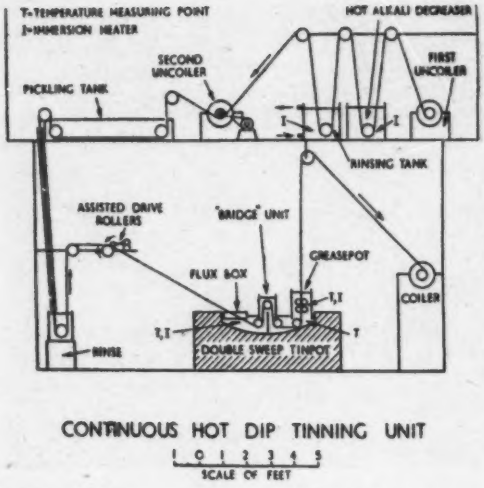


Fig. 5.—Arrangement of continuous hot-dip tinning unit for 4-in. wide strip.

uniform and lustrous coatings in the range of 16 ounces to 4 ounces per basis box, on continuous strip at high speed. Orthodox hot-dip tinning practice has been unable to compete in this weight range and the electrolytic process has offered the additional advantage that coatings of different weights can be applied on the two sides of the strip.

These advantages of the electrolytic process are achieved at the expense of much more costly plant and processing costs than are likely to apply if a hot-tinning method could be made to give the required performance. Large capital cost is caused by the requirement for electric plant and control gear to provide large d.c. currents. The processing costs are high because not only has energy to be expended in affecting the electrodeposition but the essential process of flash melting requires an amount of energy which is nearly equal to the theoretical heat requirement for hot tinning.

Recent work at the Sketty Hall Laboratories has shown that it is possible to apply molten tin continuously to preheated strip by a coating roller, without immersing the strip in the tin, in such a way that the coating weight can be controlled from about 2 lb. per basis box down to 8 ounces per basis box. The strip is cleaned by passing through a furnace containing a reducing atmosphere and the coating is carried out under a reducing atmosphere so that the coating speed is only limited by the rate of strip preheating and necessary pretreatment time. The well-known speed limitation of the orthodox hot-tinning process caused by flux carry-over is thus completely avoided and a good-quality tin coating can be obtained continuously. Also differential coatings can be easily applied.

Because of the promise of continuous hot tinning an intensive attack is being made on the development of the process. To facilitate this work, two experimental continuous hot-tinning lines have been built and are now in operation. One of these processes strip 1-in. wide by the method described above and is equipped for investigation of gaseous pretreatment and fluxing conditions and for study of the roller coating process. Fig. 3 shows the arrangement of this line. The other is designed for 4-in. wide strip and employs orthodox methods of pickling, fluxing and immersion tinning but includes special components in the grease pot so that various methods of coating weight control can be investigated. It is shown in Fig. 4. Both these lines are designed to operate at speeds up to 300 ft. per minute.

These experimental lines are equipped with suitable instrumentation so that important variables of the process such as strip speeds, strip temperature, tin-pot temperatures, and strip footage can be observed and recorded. A back scattering X-ray technique will be used for continuous measurement of the tin coating thickness on one of these lines.

The work on these experimental tinning lines is giving good opportunity for investigation of design problems arising in connexion with continuous strip-processing plant, such as continuous strip heating and instrumentation of the line. This experience will pave the way for later investigation of other continuous strip processes.

Study of Surface Conditions and Coating Quality

A laboratory concerned with coatings research must be well equipped for study of the physical conditions of the surface which influence the coating character and for study of the ultimate coating quality. The surface roughness of the base steel affects the quality of thin coatings applied and the influence increases as the coating weight is reduced. For this reason a Talysurf Profilometer has been found to be an essential piece of laboratory equipment. Good facilities are also available in the laboratory for metallographic study, particularly of sections of coatings and in this connexion colour photography has been applied with advantage.

An X-ray diffraction set is available and has been used for determination of the surface structure of ferrous and non-ferrous strip, and a method has been developed using X-ray back reflexion for assessing the amount of temper rolling to which a strip has been subjected(4).

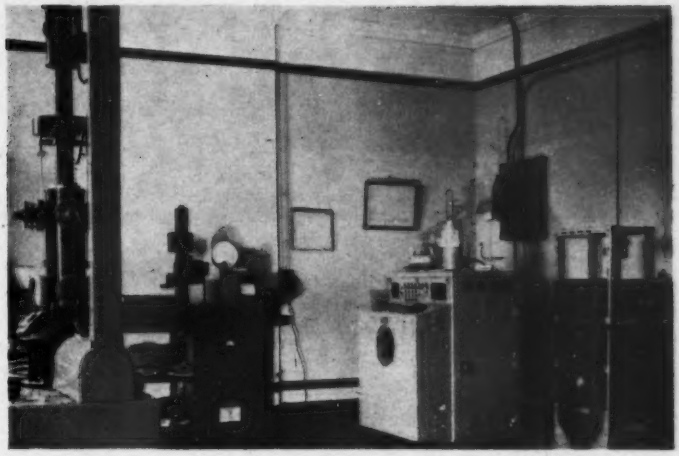


Fig. 6—The general physics laboratory showing the electron diffraction apparatus, Talysurf and x-ray equipment.

This X-ray equipment is now being used for a study of the X-ray technique for measurement of tin-coating thickness developed in the United States[3]. In this method the tinplate surface is illuminated with an X-ray source so that the base steel fluoresces and the absorption of this secondary radiation by the tin coating can be used as a measure of the coating weight.

An electron diffraction set has been found useful for the study of the structure of very thin electrodeposits, as was required in an investigation of the way in which the structure of a deposited film is influenced by the structure of the steel base. Some of this apparatus is shown in the photograph of Fig. 6.

An intensive study has also been made of the physical properties of molten binary metal alloys. This arose out of an investigation of the fluidity of commercial galvanizing baths. Measurements of viscosity, density, electrical conductivity and co-efficients of expansion were made for various alloys.

As mentioned earlier, the coatings laboratory at Sketty Hall is part of the Mechanical Working Division of B.I.S.R.A. and so is kept in close touch with all aspects of research into metal working and deformation which might influence coating processes or properties required of a coated sheet. Close linkage is also maintained with the B.I.S.R.A. Chemistry Department at the London Battersea Laboratories, which is responsible for corrosion research and testing. It is widely accepted nowadays that successful research in applied science is very dependent on co-operative effort between different groups of workers. Such co-operation and exchange of information is particularly important in a field of study with such wide ramifications as protective coatings on steel, and thus in addition to close liaison with member firms and their laboratories contact is maintained with such organizations as the British Non-Ferrous Metals Research Association, the Fruit and Vegetable Canning Research Association, the Metal Box Co. Ltd., the Tin Research Institute, the Zinc Development Association and the Hot Dip Galvanizers' Association. The Sketty Hall Laboratory has also the advantage of close proximity to, and friendly relations with, Swansea University College.

The Laboratory also does a limited amount of *ad hoc* investigation work in connexion with coating problems arising in the works of member firms. Much of this work is concerned with galvanizing and includes tests on coated sheets, coating-weight determination, metallographic studies and general trouble-shooting on coating processes. Within the limits of staff time available, these services are occasionally extended to non-members of the Association on a fee-paying basis according to the amount of work involved.

REFERENCES

(1) Salt, Dr. F. W., Meecham, Miss S., and Jepson, S. "Electrodeposition of Iron-Zinc Alloys." To be published in the *Journal of the Institute of Metal Finishing*.

(2) Hughes, Dr. M. L., and Moses, D. P. "Hot-dip Aluminizing," *Metallurgia*, 1953, Sept., 48, (287), pp. 105-122.

(3) Hughes, Dr. M. L., and Humphreys, R. "The Recovery of Zinc from Galvanizers' Dross." *Sheet Metal Industries*, 1953, Nov., 30, (319), pp. 955-968.

(4) Wright, P. W., and Hundy, Dr. B. B. "The Estimation of Temper Rolling Reductions of Mild Steel Sheet by an X-ray Diffraction Method." B.I.S.R.A. Paper No. MW/E/5/55, submitted to the *Journal of the Iron and Steel Institute*.

(5) Beeghly, H. F. "An X-ray Method for Determining Tin Coating Thickness on Steel." *Journal of the Electrochemical Society*, 1950, April, 97, (4), pp. 152-157.

A Quarterly Survey of some of the Features in Finishing Literature from Abroad

by **SCRUTATOR**

FINISHING trends and practices in the American automobile industry are always news. In this connexion, information(1) released concerning the re-engineering and re-styling of the Chrysler Corporation's five automobile lines—at an estimated cost of a quarter of a million dollars—shows that on outside trim stainless steel is being used whenever possible. To give a more exact match with other chromium-plated components, it is sometimes chromium flashed. Aluminium is rapidly finding new applications and a special staff has been assigned to promote its development. Although the trend is for its utilization in stress-bearing functional parts, it is also finding decorative uses. In some models the seat cushion moulding is made of chemically polished and anodized extruded aluminium. (H. Baur(2) has surveyed patents issued since 1940 in the increasingly important field of the chemical and electrochemical polishing of metals. Magnesium, iron, steel, copper, nickel, zinc and cadmium are considered in addition to aluminium.) In spite of the nickel shortage, the minimum electrodeposited coating thickness permitted on zinc-base die-castings such as head-light bezels has been increased to 0.0008 in., and it is claimed that bumper plating procedure has been modified to include ductile—followed by bright-nickel plating. By confining the latter to 25 per cent. of the total nickel coating thickness, it is claimed that the overall ductility is not adversely affected. Pontiac Motors(3) have also given some details of their huge new automatic bumper plating plant, which is 460 ft. long, 15 ft. wide and 18 ft. high. This machine will plate 360 bumpers per hour, consumes 50,000 lb. of nickel per month, as a result of which the anodes have to be changed fortnightly.

Practice Made Perfect

Probably no single metal finishing operation receives less care and attention than rinsing, and it is refreshing to find that this subject has been scientifically studied by Joseph B. Kushner.(4) In his paper the three essentials for good rinsing are defined; the pros and cons of no less than seven methods of agitation as well as the reasons for hot or cold rinses are critically discussed; and stress is laid on the importance of determining the correct water volume for each particular job. By obtaining maximum rinsing with the minimum water usage, both water and waste disposal costs are kept to a minimum. A useful nomograph for solving some production rinsing problems is also included.

Buffing is another operation which remains more of an art than a science, and an attempt has recently been made in America to correlate metallurgical hardness with buffability.(5) Thirteen copper deposits from eight proprietary plating baths were placed in order of buffability by two different buffers. Microhardness measurements were taken before and after buffing. Although the test did not show that the hardest coating was the most difficult to buff nor that the softest was the most easily buffed, it revealed a striking agreement between the ratings of the two buffers—a fact which most polishing shop foremen could have foreseen before the test was started.

Laboratory Topics

By now, the basic constituents of most proprietary phosphating solutions are well known and on many large installations regular solution analyses are carried out. The most widely employed types of process are those based on zinc phosphate accelerated by sodium nitrate or sodium chlorate, and a useful rapid method for the determination of sodium using an anion exchanger in the hydroxyl form has been developed by Gabrielson.(6) A maximum relative of error <0.5 per cent. is claimed for the technique, which is also applicable to the determination of alkali metal in cyanide plating baths.

A " spot test " is usually employed for thickness determinations on decorative chromium electrodeposits, but it has been suggested(7) that the interference microscope or microinterferometer is also a valuable supplementary tool for settling coating thickness disputes between purchaser and supplier. This technique utilizes the principle of optical interference to make absolute measurements of irregularities on reflective surfaces in the range 0.000002—0.0001 in. and on matt surfaces providing the surface roughness does not exceed 0.00003 in. peak to valley. Special stripping techniques have been developed for removing the chromium deposits from copper, nickel, steel or stainless steel so that a satisfactory " step "

(continued in facing page)

THE INSTITUTE OF VITREOUS ENAMELLERS

Spring Meeting 1955

Visits to the Margam, Abbey, Trostre and Velindre Works of THE STEEL COMPANY OF WALES LTD.

AN invitation has been extended to the Institute of Vitreous Enamellers by the directors of the Steel Company of Wales, to visit the works of the company at Port Talbot, Llanelly and Velindre on Thursday and Friday, May 19 and 20, 1955. In conjunction with these visits a social programme has been arranged with headquarters at the Seabank Hotel, Porthcawl, at which members' ladies will be welcome. A special excursion has been arranged for the ladies to the Welsh Folk Museum at St. Fagan's near Cardiff on Friday May 20.

Application forms in respect of this meeting have been circulated to members and these should be completed and returned to the Secretary as soon as possible and in no case later than May 6, 1955. A separate reply form is required for each member or company member employee and further copies of the form can be obtained from the Secretary.

Programme

Thursday, May 19th. Coaches will depart from the Seabank Hotel, Porthcawl at 12 noon for luncheon at the Grand Hotel, Port Talbot, by invitation of the company. After luncheon visits will be made to the Margam and Abbey Works where tea will be provided by the company before return to Porthcawl for approximately 5.30 p.m. Members can join the party at Port Talbot, where transport will be available to convey any ladies direct to Porthcawl.

In the evening there will be a dinner party followed by a visit to the Pavilion Theatre, Porthcawl, for a performance of "The Master of Arts" by the Cardiff Little Theatre.

Friday, May 20th. Coaches will depart from the Seabank Hotel at 9.00 a.m. for Llanelly to visit the Trostre Works in the morning. After luncheon, to be provided by the company, the party will proceed to Velindre to see the new works in course of construction before returning to Porthcawl at approximately 5.00 p.m.

In the evening there will be a dinner at the Seabank Hotel at 7.30 p.m. followed by dancing.

Overseas Review

(*continued from previous page*)

between the plated and non-plated area is produced, which can then be measured by the interference microscope.

Paint Bonding

The production of protective coatings on iron and steel surfaces using high temperature steam is not new, and treatments which have found a greater or lesser degree of success—mostly the latter—include the Bauer-Barff, Wells, Bradley and Bontempi processes. The "new" steam oxidation process used by Singer Manufacturing Co., Bridgport, Conn.(8) is claimed to provide an excellent paint base at an estimated cost of 20-25 per cent. less than that of chemical surface preparation. An additional advantage over the customary "wet" processes is that steam oxidation obviates the possibility of liquid chemicals becoming trapped during processing and seeping out in service, thereby producing paint failure. Steam oxidation is performed in a modified Leeds and Northrup pit-type, sealed retort, forced circulation furnace. This is heated to 650° F., the degreased steel components introduced and when temperature has been regained, steam at 5 lb. per square inch pressure admitted and the temperature reset to 750° F. Steam is then passed through the furnace for 15 minutes, the outlet valve closed, and processing continued for a further 35 minutes. The work is then removed and allowed to cool. Cast iron requires both higher processing temperatures and longer treatment times.

Last Straw

So far, psychology has made very little inroads into the metallurgical technical press. An article entitled "Wives; What they Think About Husbands" has, however, recently appeared in *Iron Age*.(9) This describes "counselling sessions for employees' wives" at which "wives tell what bothers them most about their mates." Let us hope for all our sakes that this practice or this type of article is not destined to spread into the metal finishing field!!

(1) *Materials and Methods*, 1955, Jan., 41, (1), p. 83-88.
(2) *Metalloberfläche*, 1955, Feb., 9, (2), p. 22A-28A.
(3) *Plating*, 1955, Jan., 42, (1), p. 70, 85.
(4) *Metal Finishing*, 1955, Jan., 53, (1), p. 76-79.
(5) *Plating*, 1954, Dec., 41, (12), p. 1422-1425.
(6) *Metal Finishing*, 1955, Feb., 53, (2), p. 58-60.
(7) *Plating*, 1955, Jan., 42, (1), p. 55-57.
(8) *Iron Age*, 1955, Jan. 13, 175, (2), p. 75-77.
(9) *Iron Age*, 1955, Jan. 27, 175, (4), p. 37-38.

Modern Methods for the Measurement of METAL SURFACE FINISH

by LEO WALTER, A.M.I.Mech.E.

SURFACES of materials vary a great deal in appearance and geometrical features, and the microscope reveals characteristic surface textures of engineering materials. Three main types of irregularities in surface finish can be usually distinguished. First, a metal surface before or after machining has a certain "roughness". Irregularities are usually only a few thousandths of an inch in width, and their depth can only be expressed in micro-inches, *i.e.*, in millionths of an inch. Nevertheless, a coarse surface finish, if magnified, looks quite different from a finely ground metal finish. Associated with these are surface undulations, and this is usually referred to as "waviness". A third irregularity is known as "flaw", and can be detected by special instruments even if invisible to the naked eye. Scratches, cracks, holes, etc., can be, however, discovered by close visual inspection. Fig. 1 is reproduced from American Standard Specification ASA-V-46.1 (1947) and illustrates the above-mentioned terms. In surface finish the roughness is the predominant factor, and can be regarded as being superimposed on a wavy surface. Magnified, a rough surface appears as a waveline with peaks and valleys. By changing the wave length, *i.e.* the horizontal distance between the crosspoints of the waveline with the centre-line, a smooth surface can be transformed into a rough surface, without altering the "height" of the wave, *i.e.* the peak-to-valley depth.

In theory three main waveforms can be distinguished, similar to those shown in Fig. 1a. These basic surfaces can be square, or triangular, or have a sinusoidal shape. In practice any combination of these shapes can be obtained according to material and machining method used. In spite of the same depth, the appearance may be different according to actual waveform, and measurements have to be devised which give a useful indication of the change in surface texture on metal components produced by the same machining process but using different tools and tool speeds.

In the machining of metals many practices and customs have been developed without scientific background, and specifications of surface qualities remained for a long time somewhat vague. On first sight the measurement, and hence the specification of surface roughness appears to be quite simple, but before clear and full specifications, based on a sound foundation can be written in a generally acceptable form, several difficulties will usually have to be overcome. In the first instance any more scientific definition of a surface finish requires knowledge of the micro-geometric features. Factors such as percentage of effective bearing area in case of lubrication of bearings, or the shape, arrangement, occurance and, last but not least, the depth as shown in Fig. 1a, can have importance in addition to fitting tolerances. The innumerable number of variations of the above factors, becoming visible under the microscope, especially under great magnification under the electron microscope require studies which far exceed the usual training of works personnel. Nevertheless the latter should be familiar with at least a few basic facts.

At the present time a number of methods and instruments are available for use in the machine shop, as distinct from the research laboratory. Most instruments for practical purposes act on a very short surface profile, but with elaborate

Fig. 1.—Surface roughness, flow and lay
(From U.S. Standard Specification A.S.A.-V-46,1(1947).)

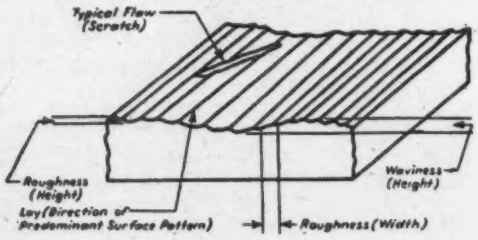
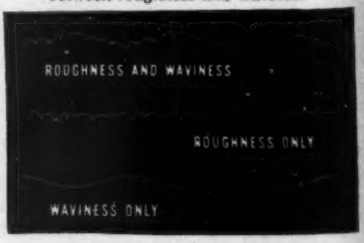
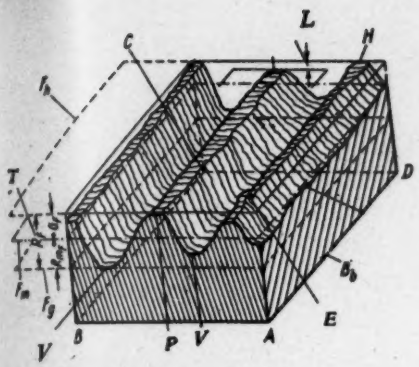


Fig. 1a.—Diagram illustrating difference between roughness and waviness





L = longitudinal roughness

T = transversal roughness

P = peak *V = valley*

E = edge *Fh = cover surface*

Fm = average plane *Fg = basic plane*

Rf = roughness depth *Gf = polish depth*

Fig. 2.—Diagram illustrating terms used in connexion with surface phenomena

laboratory instruments a graphic record is traced. For example, a tracing point or stylus moves over the tested surface, and it depends on the radius on the pointed end how deep it will penetrate into the valleys of a surface. British Standard 1134: 1950 deals with the assessment of surface texture in an easily understandable way and should be known by everybody concerned with producing or testing surface finish.

Modern devices, such as pneumatic surface gauges, or instruments using electronic amplification of minute measuring impulses produce in practice figures or graphs for immediate use to the production inspector, but the possibility of errors cannot be excluded. Friction, inertia, errors caused in pivots, linkwork, etc., can sometimes be misleading. The least number of mechanical errors can be expected from comparison blocks, but this oldest and most widely used method depends on individual judgement by the human eye. It is obvious, as will be seen later in this survey, that a simple "roughness number" cannot take all factors of micro-geometry into consideration. Over-simplification of the various problems in the past by using standard comparison blocks has now been often replaced by having available a separate reference block for each type of surface and material, prepared by exactly the same method of machining on the same material as the job to be examined. Summing up, the correct assessment of the microgeometric properties of a surface is not a simple job at all. As suggested by Mr. R. H. Field of Ottawa (*see* bibliography) the first most urgent step in basic research is to prepare a list of agreed definitions applicable on an international scale.

Fig. 2 shows an attempt to define certain terms used in practice and several expressions are illustrated with regard to waviness in general.

Methods of Evaluation

Surface roughness can be assessed either by comparison with reference surfaces, or by direct measurement. For comparative methods standard roughness blocks consist of a set of metal blocks varying in quality from a smooth-lapped, honed, or ground surface, to a rough-milled, sawn, or flame-cut surface. Each block is lettered; any comparison is by sight and feel. Stylus-type instruments, such as the Profilometer, employ a stylus which is moved over the surface following the profile contour, and shows the waves by means of an amplifying unit and a micro-inch meter. This instrument and others will be described later. As mentioned before, in making comparisons, care should be exercised to avoid errors due to differences in material, contour, and type of operation represented by the reference surface and the work.

In using instruments for comparison, roughness measurements, unless otherwise specified should be taken across the lay of the surface, or in the direction which gives the maximum value of the reading.

Standard Blocks

Standard roughness blocks consist of a set of metal blocks varying in surface quality from a smooth-lapped, honed or ground surface to a rough-milled sawn or flame-cut surface. For example, the complete set made by the American General Electric Co. consists of 10 blocks, each 2 in. × 2½ in., designated by a letter. Since different commonly used methods of surface processing have different appearances, even though the depth of the irregularities may be the same, several of the blocks are subdivided into two of four different surfaces of the same degree of roughness, but produced by different type machines, giving a total of 25 surfaces. The characteristics of these blocks are given in Table I.

Each specimen represents the roughest surface acceptable for the particular designation symbol, regardless of the method of producing the finish or the nature of the material. Smoother surfaces are acceptable if produced at no extra cost, except where a smoother surface might not satisfy the functional purpose intended.

These specimens enable the engineer or draughtsman to select and specify by symbol the degree of roughness allowed for a particular

TABLE I*

Roughness in Micro-inches				Typical Methods of Producing
Symbol	Symbol	Average†	Peak-to Valley‡	
A	f^1	4	15	Ground, lapped, honed, micro-honed, superfinished, etc.
B	f^2	8	28	Ground, lapped, honed, micro-honed, superfinished, moulded, drawn, etc.
C	f^3	16	56	Ground, lapped, honed, reamed, scraped, superfinished, bored, burnished, planished, milled, moulded, precision-cast, cold-pressed, drawn, extruded, etc.
D	$f^{3\frac{1}{2}}$	32	118	Ground, broached, reamed, scraped, turned, bored, burnished, milled, planished, moulded, precision-cast, cold-pressed, drawn, extruded, etc.
E	f^4	63	220	Ground, broached, rolled, shaped, turned, bored, milled, abrasive cut-off, reamed, moulded, precision-cast, extruded, drawn, etc.
F	f^5	125	455	Ground, broached, rolled, reamed, shaped, turned, bored, milled, drilled, spot-faced, counterbored, filed, punched, abrasive cut-off, moulded, precision-cast, extruded, forged, etc.
G	f^6	250	875	Ground, rolled, shaped, turned, bored, milled, drilled, spot-faced, counterbored, filed, punched, sand-cast, forged, precision-cast, etc.
H	$f^{6\frac{1}{2}}$	500	1,750	Ground, gas-cut, chipped, shaped, turned, bored, milled, sawed, filed, punched, sand-cast, forged, etc.
J	f^7	1,000	3,500	Ground, gas-cut, chipped, shaped, turned, bored, milled, sawed, sheared, nibbled, welded, punched, sand-cast, forged, etc.
K	f^8	2,000	7,000	Gas-cut, chipped, shaped, turned, milled, sawed, sheared, nibbled, welded, parting cut, sand-cast, etc.

* *By Courtesy of General Electric Co., Schenectady, N.Y.*
† Determined by a Profilometer, or calculated.
‡ Determined by a Brush surface analyzer, a profile recorder, or calculated.

surface. Upon examining the specimen which corresponds to the symbol specified in the drawing, the shopman can visualize the type of surface and roughness he is to produce. Later, the inspector can determine whether the roughness meets the specification by comparing it with the specimen.

Tests by the American General Electric Co. indicate that roughness cannot be satisfactorily judged below 4 micro-inches average, but there appears to be no upper limit. It was also concluded that specimens above 4 micro-inches which vary in two-to-one steps (*see* Table I) of roughness can be consistently distinguished, provided they are specimens made by the same or similar methods of machining.

Standard blocks are usually prepared by the replica method, although excellent machined stainless-steel specimens, or specimens depicting various grinding finishes are available.

Stylus Instruments

Stylus-type instruments employ a stylus (or exploring probe) which is moved over the surface, across the lay, and follows the profile contour. The average up-and-down movement of the stylus is indicated by a meter, or a curve is plotted which corresponds to the path traversed by the stylus. One instrument of this type called the Profilometer consists of a tracer unit, and amplifying unit, and a micro-inch meter. (*see* Figs. 3 and 3a).

It is a direct-reading instrument and the tracer has three or more feet or skids which enable it to ride over the surface and establish a reference

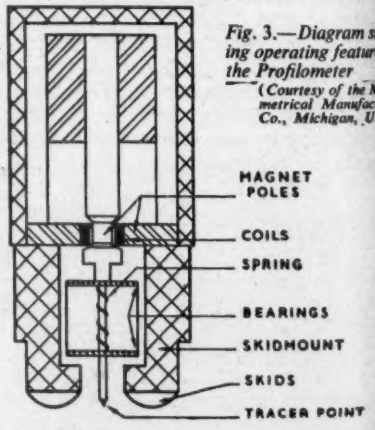


Fig. 3.—Diagram showing operating features of the Profilometer
(Courtesy of the Micrometrical Manufacturing Co., Michigan, U.S.A.)

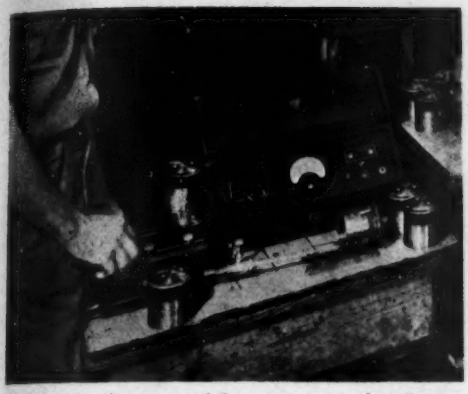


Fig. 3a.—Profilometer used for measuring surface finish in the workshop (Courtesy of Gaston Marbaix Ltd.)

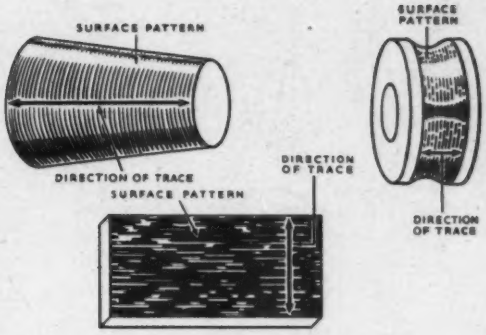


Fig. 3b.—Directions of measurement at right-angles to lay pattern

plane. It incorporates the stylus, which explores the roughness as it moves up and down in relation to the skids. A coil mounted on the stylus is energized by its movements in the magnetic field produced by two magnetic poles. The current thus induced is proportional to the vertical movement of the coil, and is amplified by electronic means. The amplified current actuates an indicating instrument which is marked in micro-inches, average.

The tracer can be reciprocated over the surface by hand or by a motor. Motor tracing gives more consistent results. Special tracer heads are provided for irregular shapes, such as gear teeth and small holes.

It is claimed by the makers of the Profilometer that the points most stressed by users is the fact that it can be brought into the workshop and surface measuring done actually on the component while it is still in the machine. On the other hand it is claimed to be so versatile that it can check components of many shapes which do not yield to other measuring methods, such as measurement of roughness of trust bearings produced on a wet grinding machine, or of pistons, internal conical surfaces, of glass samples between grinding and polishing, and many more. (Fig. 3b).

The readings produced by the Profilometer can be described as the average departure from a centre-line, which latter can theoretically be drawn halfway between peaks and valleys. As an electronically operated instrument, an infinite number of vertical deviations is measured in computing the average.

Fig. 4 illustrates industrial finishes, whereby the ranges of roughness are given in micro-inches. Tracer calibration is performed by comparing the up-and-down excursions of the diamond point by means of a microscope, with a known standard of length.

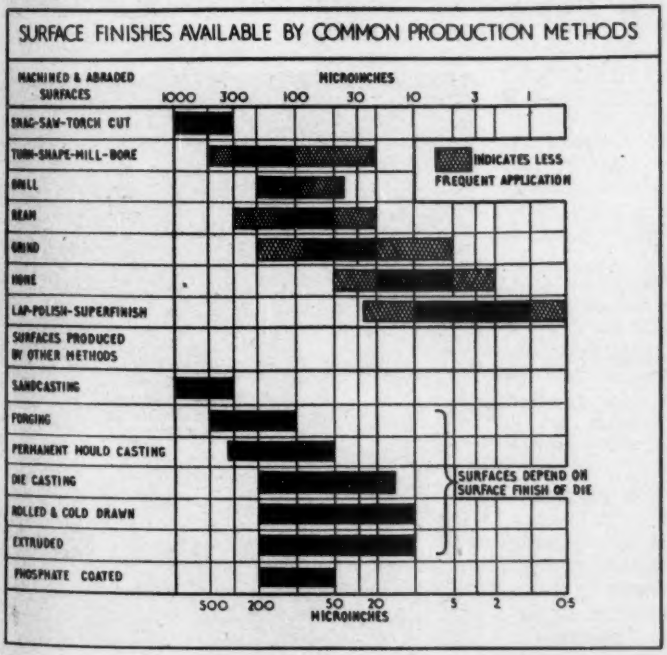


Fig. 4.—Surface finishes available by common production methods

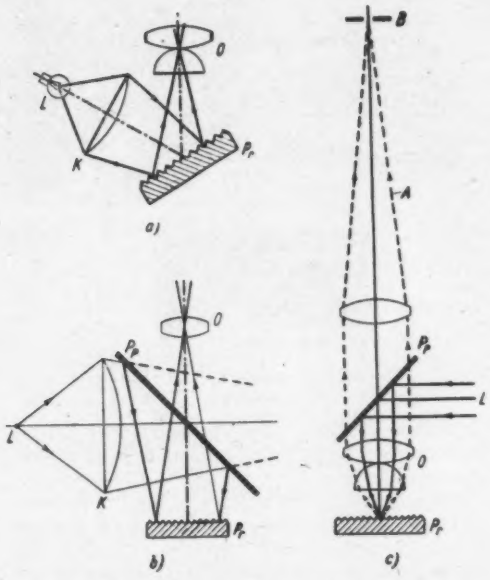


Fig. 5.—Surface illumination equipment for optical comparison

Use of Microscopes

A great number of scientifically designed special microscopes is now available for inspection of surfaces.

Fig. 5 illustrates methods of producing an illuminated surface for the microscope. Shown at (*a*) is an inclined position for object Pr. with the light bulb L, prism K and objective O. In (*b*) is used a plate glass Pp inclined under an angle of 45 deg. between objective O and test-piece Pr. A vertical illuminator with plane glass Pp and objective O, which latter also produces illumination from a light source L is shown at (*c*). The light rays for reproducing the image are A, and B is the ocular for the eye.

Fig. 5a shows a special microscope for comparison purposes having two separate objectives, one for the sample and one for a standard block, with a common ocular. The eye sees then both objects side by side in the same light; (l) is the specimen, (n) the objective, (k) is the standard piece under objective (m). Knobs (d) and (c) serve for adjustments, and (a) is the common ocular.

For scientific observations, the electron-microscope is now available in laboratories, universities, etc. In such microscopes the electrons produced by a filament are accelerated by a high voltage and formed into a narrow beam by means of a condenser lens, which consists of an electromagnet which influences the path of electrons in the same way as a normal lens does with light rays.

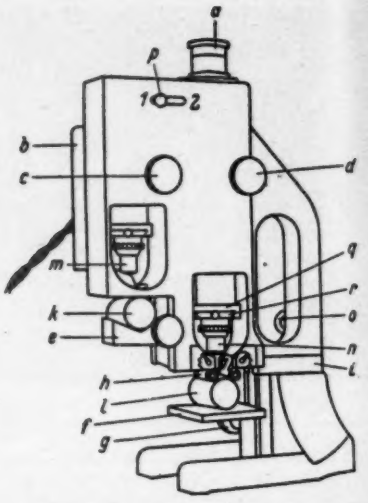


Fig. 5a.—Busch microscope for comparison of standard with test object

Fig. 6 shows the newest development of Philips Electrical Ltd., namely the Philips 75-kV electron-microscope, which is low-priced and designed for widest use in the machine-shop laboratory. Only a single-phase supply and no water-cooling is required for this new versatile instrument.

Fig. 6.—Philips 75-kV electron-microscope

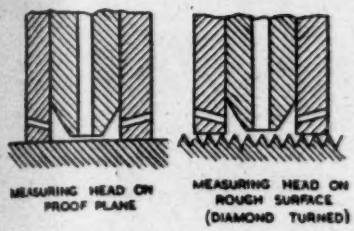


Fig. 7.—(above) Measuring head of pneumatic gauge

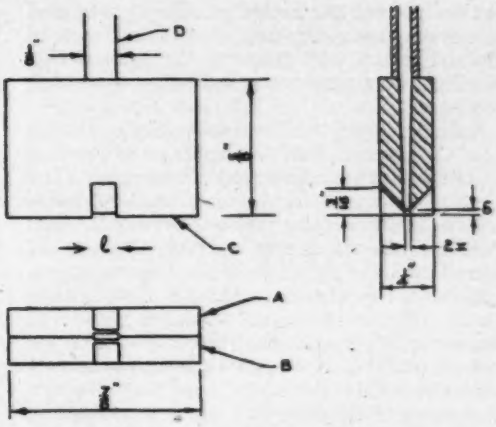


Fig. 8.—(right) General dimensions of air-jet head

Pneumatic Gauging

A number of pneumatic surface test methods have been developed in recent years. The general principle consists in observing the resistance to the escape from an air jet, the delivery from which is controlled by the dimension of the component being measured. Fig. 7 illustrates, on the left, the measuring head on a proof plane, and, on the right, set on a rough surface. One surface is finished by optical polishing and the other by diamond turning.

Two alternative types of pneumatic comparator developed for precision linear measurements of length have been adapted at the National Physical Laboratory at Teddington for assessing the variations in surface texture. Each unit is capable of high sensitivity with a good speed of response; their respective working elements are briefly described:

In the piston-type comparator (National Physical Laboratory). (Fig. 9), the essential elements consist of a hollow piston which is a good sliding fit inside a cylinder of ½-in. bore. Compressed air, maintained at a constant pressure by a precision pressure regulator, is supplied to the centre of the cylinder whence it flows downwards through the hollow piston to the control orifice. After flowing through the control orifice the air passes to the lower part of the cylinder and then by means of a short length of small-bore flexible tubing, to the measuring head. As the escapement area at the measuring head varies according to the roughness of the surface the corresponding change in the pressure underneath the spring-loaded piston results in a small displacement of the piston which is indicated on a dial gauge. The effect of static

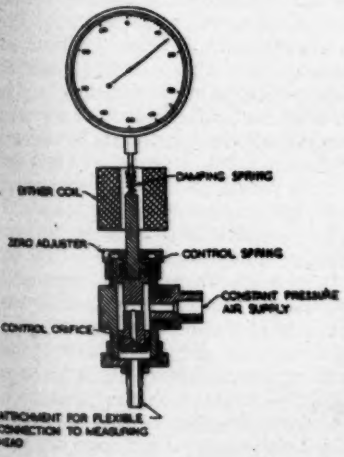


Fig. 9.—(left) Piston-type comparator, developed at the National Physical Laboratory

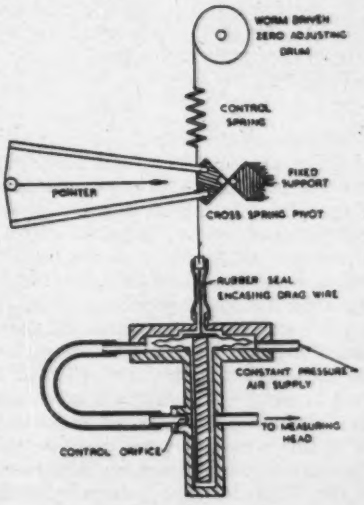


Fig. 10.—(right) Sectional diagram of diaphragm-type surface comparator
(Courtesy of the Sigma Instrument Co. Ltd.)

friction between piston and cylinder is overcome by vibrating the piston over a small amplitude in an axial direction by means of the "dither coil" supplied with alternating current at mains frequency.

A diaphragm-type comparator (Sigma Instrument Co.) using a flexible diaphragm in place of the piston, has been developed commercially. The essential details are shown diagrammatically in Fig. 10; air at constant pressure is passed to the outside of the diaphragm and then through the control orifice to the inside of the diaphragm and finally to the measuring head. The force corresponding to the differential pressure across the diaphragm is transmitted by the drag wire to the control spring. In operation, variations in escapement area at the measuring head thus produce movements of the drag wire which are amplified by a mechanical lever system and the final result is indicated by the angular movement of a pointer across a scale.

Use of Optical Flats

During recent years the fact that optical interference patterns enable surveying finished surfaces with considerable accuracy has drawn the attention of machine-shop inspectors to this comparatively easy method. Briefly, an optical flat used with monochromatic light produces light band readings which measure flatness of a surface. The only condition for use of this optical method is that the surface itself must be shiny and smooth so that light can be reflected back through an optical flat. Thus an interference band pattern produced can be analyzed and interpreted in terms of specific flatness. Different patterns are produced by flat, concave or convex surfaces. For example, straight, parallel and equally spaced bands indicate a nearly ideal flat surface finish within about one millionth of an inch. Sources of monochromatic light can be a helium-filled lamp and a mercury-vapour lamp.

Ultrasonic Methods

During recent years the use of ultrasonic waves for non-destructive testing of materials has come into wide operation for detection of flaws in metal components, etc. Pulses of ultrasonic sound waves are produced by means of piezo-electrical effects using special crystals. Electrical oscillations are thus converted into mechanical vibrations of high frequency. These inaudible "sound" waves travel through material and when they encounter any discontinuity they are reflected back to the search unit. These reflected waves are portrayed as a definite pattern on a cathode-ray-tube unit. It is, however, also possible to locate surface or sub-surface discontinuities. A typical instrument is the "Reflectoscope", manufactured by Sperry Products, Inc. of Danbury, Conn. U.S.A. A surface wave search unit can be used in conjunction with the instrument; a beam of ultrasonic vibrations is projected long the material surface and locates irregular finish. It is notable that these vibrations will travel around irregular shaped surfaces.

Fig. 11.—" Surfindicator "
(Courtesy of Brush Electronics Co., Cleveland, Ohio, U.S.A.)

A new versatile surface inspection instrument for the machine shop has been developed in America by General Motors, and is manufactured under the trade name of Surfindicator by Brush Electronics Co. of Cleveland (Fig. 11). The equipment consists of a pick-up section, consisting essentially of a diamond stylus which is used as a "feeler" to follow surface contours. A transducer for producing ultrasonic (inaudible) waves in the form of a vacuum electronic tube converts stylus motion into an electrical signal, and there is a viscous coupler for damping stylus motion. The indicating instrument contains an amplifier, an indicating meter and a power supply for the pick-up tube. It is interesting to note how, as the pickup of the Surfindicator is passed across a surface, the rising and falling motion of the stylus riding over peaks and valleys is transformed into electrical signals, and how they are averaged and indicated.

The tip of the stylus is a conical diamond of 90 deg. leg included angle with a spherical tip of 0.0005-in. radius. It affords sufficiently good

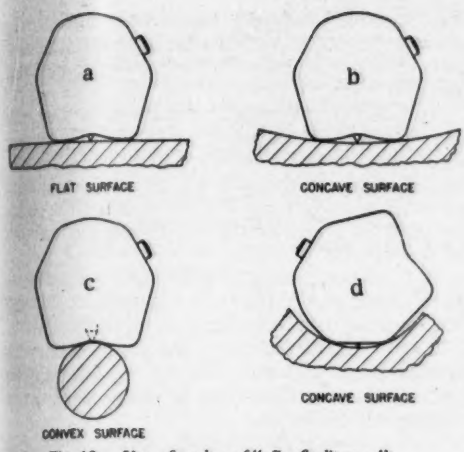


Fig. 12.—Use of stylus of "Surfindicator"

penetration of the scratches normally found in machined surfaces to permit accurate roughness measurement. The mechanism on which the stylus is mounted provides the force which holds it in engagement with the surface. This force (about 1 gm.) is independent of the force which is exerted on the pickup assembly.

Large-radius spherical riders, one on either side of the stylus, and with their centres of curvature in line with the stylus, are used to provide the reference surface which is followed. The riders are of sufficiently large radius so that they follow only the nominal surface of the piece being inspected, and are not affected by fine roughness grooves.

For versatility in operation, the turret rider head, which is fitted onto the end of the pickup case, can be used in any one of three positions. Each position has been designed for use on a range of surface contours. The four sketches in Fig. 12 show the rider in its most used positions. Note that the surfaces which contact the work have about $\frac{1}{4}$-in. spherical radii and their centres are spaced $\frac{3}{8}$ in. apart. These illustrations show the wide variations which occur in the nominal stylus position.

The rider position shown is for use on inside diameters from a minimum of $\frac{7}{8}$ in. to 4 in. Note that here too, the contacting surfaces have a longitudinal radius of $\frac{1}{4}$ in., but now, the radius of the skid in the axis perpendicular to the pickup is reduced to $\frac{1}{8}$ in. and the spacing between centres of curvature is $\frac{3}{16}$ in.

A third rider position provides a single skid of $\frac{1}{4}$ in. spherical radius located directly ahead of the stylus. This rider requires additional support such as a motor trace means or a fixture which provides support at the rear of the pickup case. Furthermore, this last rider should not be used on very rough surfaces since the relatively small rider radius would not follow a true nominal surface and incorrect readings would result.

The handle, provided for use with the pickup as a manual tracer, has also been designed to protect the pickup stylus when not in use.

To obtain an electrical signal from stylus displacements of the order of millionths of an inch, a movable plate vacuum tube transducer is used.

The highly sensitive transducer produces fairly large voltage variations with small mechanical input, thus making necessary only a minimum of electronic amplification and simplifying and lowering the cost of the inspection instrument. Furthermore, the tube used in the Surfindicator puts out a plate voltage which is directly related to the displacement. In other words, the low-frequency response of the instrument is not limited by the transducer characteristics. There is no direct connexion between the stylus and the plate rod extension of the transducer. Instead, connexion is by means of a viscous coupling.

In practice the operator guides the pickup carefully over the piece to be inspected, and then reads surface roughness in average micro-inches on the instrument scale of the meter. This method permits the specification of surface roughness on the blueprint and then the measurement of it in the machine shop.

The Use of Electron Diffraction

An interesting electron diffraction apparatus has been designed by Prof. G. I. Finch of Imperial College, London, which uses a diffraction camera for producing photographic plates. Electron diffraction can be applied to investigations of the effect of machining on metal surfaces. A controlled beam of electrons is directed on to the surface to be examined. It is then reflected on to a fluorescent screen or a photographic plate, and the diffracted electrons produce a definite pattern. This latter varies distinctively with the structure of the surface, which latter may be determined. Effects of machining—and of everheating as a consequence—on a metal surface may be readily determined by this method. Other uses are the study of electrodeposition on metal finishes, and examination of metal components which have been taken out of service (plastic deformation, used turbine blades, etc.).

In a brief survey only a few methods and instruments can be dealt with, but the author would refer readers who wish to study the subject of measurement of surface roughness to the Bibliography. In conclusion the writer wishes to thank the many firms who have supplied data and illustrations.

(*Bibliography in page* 176)

The Nature and Significance of Mill Additions in Vitreous Enamelling (*continued from page* 158)

The use of quartz in ground coats at about 5 to 10 per cent is very popular since it helps the enamel to resist prolonged firing. In even higher proportions it is of benefit where the enamel is used on poor quality iron. Its function here is to increase the bubble structure, and to strengthen the enamel layer mechanically rather in the way that ballast or sand strengthens cement.

Enamellers have long realized the deficiencies of clay as a mill addition as far as its effect on the fired enamel is concerned. It increases the firing temperature, reduces the gloss and acid resistance, and lowers the coefficient of expansion. Recently an I.V.E. committee under the chairmanship of Mr. James Gray published the report of its investigations on the use of organic suspending agents to replace clay, and it may be of interest to summarize their findings.

Many organic colloids, such as gums, alginates, and cellulose compounds will dissolve in water to give very viscous solutions, and will produce films of very high tensile strength upon drying. An enamel milled with a small percentage (of the order of ¼ per cent) of one of these materials in place of clay will have a high biscuit strength, improved acid resistance, and usually a better gloss, although the thermal shock resistance may be lowered, owing to higher coefficient of expansion and reduced resilience arising from a diminished bubble structure.

The slip made up in this way is not very satisfactory in use since these organic materials do not give a set in the way that clay does, and the frit settles out quickly. Addition of a small amount of bentonite was tried, and a moderate set was obtained when barium chloride was used as the electrolyte, but these millings are not yet suitable for large-scale production, although they may help in producing brilliant colours in clear frits where the opacity introduced by clay is a distinct disadvantage.

WATER. There are probably as many different waters as there are enamel shops, ranging from the soft mountain waters with a hardness of only 10 parts per million, to the hard waters of the Midlands with a hardness up to about 800 p.p.m. The term "hardness" refers to the quantities of calcium and magnesium salts present, which combine with soaps to form non-lathering compounds. A hard water may therefore introduce about ½ oz. of the powerful setting-up salts of calcium or magnesium into the milling of 100 lb. of frit. Furthermore soft waters may be slightly alkaline, and may therefore deflocculate the clay. Hard waters will therefore give a higher-set enamel than will soft waters. This is shown in Fig. 1, where the clay suspension made up in water softened by ion exchange is in a deflocculated condition compared with the raw water and with distilled water.

The important thing, of course, is that the quality of the water shall be constant, and any deficiencies in set can be made good by the addition of the correct amount of calcium, barium or magnesium salt at the mill. It is not advisable to use more clay since this will reduce the mobility of the slip.

It is certainly advisable for the enameller to have an analysis of his water supply since this will help him not only in deciding on his mill additions, but also his choice of boiler-water treatment. A lead could also be given by the frit supplier who could state the type of water used when issuing mill formulae.

Where a water is very soft and alkaline and is very difficult to set up it would probably be possible to harden it artificially by passing it through an ion exchange bed to replace sodium by calcium ions, the reverse of the usual softening process.

In this paper a great deal has been left unsaid about mill additions, but in conclusion it should be emphasized that mill additions are chemicals, and only by understanding something of their chemistry will the enameller make the fullest use of his mill additions.

Metal Surface Finish (*continued from page* 175)

Bibliography

Field, R. H., "Measurement of Surface Roughness", *Canadian Machinery*, 1954, April.

Underwood, A. F. and Bidwell, J. R., "New Instruments for Roughness Measurement", *Brush Strokes*, 1953, December.

"Surface Analysis with Optical Flats", *Mechanical World*, 1954, April.

"Measurement of Surface Finish", (Summary of papers from Symposium at National Physical Laboratory, Teddington), *Product Finishing*, 1953, December.

Scheephorst, A. J. F., "The Electron Microscope", *Philips Serving Science and Industry*, 1954, January.

Williams, A. E., "Examination of Surface Structure by Electron Diffraction", *Indian and Eastern Engineer*, 1954, March.

Cronshaw, H. B., "Determination of Texture" (Section of The Instrument Manual), *United Trade Press, Ltd.*, 1953.

Walter, Leo, "How to Measure Surface Finish", *Canadian Machinery*, 1953, December.

Graneck, M., "Application of Pneumatic Gauging to Surface Finish Measurement", *Compressed Air Engineering*, 1952, November.

Perthen, J., "Oberflaechen Pruefung" (Surface Testing), *Archiv fur Technisches Messen*, 1953, January.

Reason, R. E., "Conference on Surface Finish", *Proceeding Inst. Mech. Engineers*, 1945.

Reason, Hopkins and Garwood, "Report on Measurement of Surface Finish by Stylus Methods", *Taylor, Taylor and Hobson, Ltd.*, 1944.

Graneck M. and Wunch, H. L., "Application of Pneumatic Gauging to Surface Finish Measurement", *Compressed Air Engineering*, 1952, November.

Brosheer, B. C., "How Smooth is Smooth?", *American Machinist*, 1948, September 9 and 23. New York.

Broadston, G., "Practical Aspects of Surface Finishing Instrumentation", *Iron Age*, 1947, March 20.

Zeiss, C., "Introduction into Basic Optics of Microphotography", (Bulletin, Mikov 505), 1938 (in German).

Broadston, J. A., "Surface Finish Measurement Instrumentation—A double Challenge". Paper read at Conference Instru. Soc. of America, Pittsburgh, 1946, September.

Mikelson, W., "Surface Roughness Measurement and Inspection". Paper read as above.

"Report on the Measurement of Surface Finish by Stylus Methods" *Taylor, Taylor and Hobson, Ltd.*, Leicester ,England, 1947.

A Students Guide to Examination Courses in Metal Finishing

II. Intermediate

Compiled by A. ALEXANDER

Lack of success in passing examinations arises almost as frequently from failure to apply knowledge properly as from failure to acquire knowledge. This series of articles is intended to assist actual and intending entrants for the City and Guilds Certificate Examinations in Metal Finishing to answer examination questions in the most effective manner.

(*Series continued from page* 122, *March*, 1955)

UNDER the new syllabus the Intermediate Course of the City and Guilds of London Institute is timed to take up three years of part-time study. The first two years of this are devoted to Chemistry, Physics, Mathematics and Engineering Drawing, and Metal Finishing does not enter into the syllabus.

Many candidates may consider this to be something of a waste of time and for the most part those engaged in metal finishing are anxious to obtain instruction on their own subject. It must be emphasized, however, that it is quite useless for a candidate to proceed to try to learn the basic principles of electrodeposition unless he has a good knowledge of elementary chemistry, physics and mathematics.

Unfortunately, metal-finishing courses at technical institutes are only available in a few special areas and there may be many who wish to take the examination but are unable, for various reasons, to present themselves for instruction at an area where such courses are available. It is the object of these articles to assist prospective candidates for the examination, particularly in areas where the full course is not available. But in practically every industrial centre it is possible to take the standard courses in chemistry, physics and mathematics. Those who have passed a School Leaving Certificate will probably not require to take the first year's instruction, but a candidate who proposes to study for the examination must have a sound basic knowledge of the three subjects mentioned, and it cannot, therefore, be too strongly emphasized that he should obtain instruction on these subjects from his local Technical Institute. These articles are being written on the assumption that this has been done and the reader is expected to have acquired the necessary knowledge before starting to read this series.

The Intermediate examination is in itself somewhat of a theoretical nature, it being felt desirable to test the candidate's basic knowledge of the elementary underlying principles, although a certain amount of practical work is also incorporated in the syllabus. After completing the Intermediate syllabus and passing the examination the candidate will then have a further two years to study electrochemistry, physical metallurgy and electrodeposition of metals and metal-finishing processes.

In the following series of articles it is proposed to deal first with the Intermediate and then with the Final syllabus for the examination in metal finishing.

INTERMEDIATE—PART I

Principles of Metal Finishing

General Nature of Metals

It is quite obvious that anyone who is dealing with metallurgical processes must understand the nature of the materials involved. During his course in chemistry the student will have learned that metals are elements, that they are composed of atoms and probably he may also be aware that these atoms are arranged in the form of crystals. He may learn something of the chemical properties of the metals but very little of their physical properties, particularly how they behave on being worked.

A student of chemistry who is used to dealing with crystals of washing soda, copper sulphate, etc., may be somewhat surprised to be told that a piece of copper is in point of fact, an aggregate of crystals. The crystals of this material will not look to him like the crystals of chemical salts with which he is familiar. However, if he cuts a section of a copper article and after having carefully polished the surface, slightly etches it with a suitable acid, he will see a pattern appear on the surface which on close inspection shows a number of small regular areas. (Fig. 5). These are actually crystal faces, each face etching somewhat differently and therefore showing up in contrast. If a piece of metal is fractured and the fracture examined under a low-power magnifying glass, the same general effect will be observed, although in this case there will be a certain three dimensional effect. Each one of these small areas is a crystal, that is to say, that the atoms com-

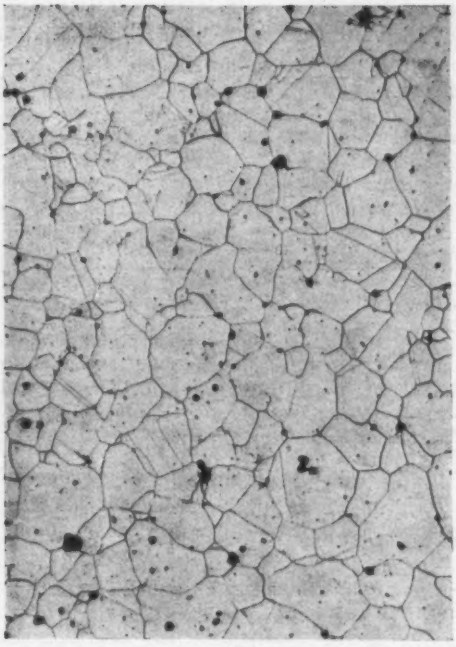


Fig. 5.—Appearance of a polished etched copper surface when viewed under the microscope showing the crystalline formation.

posing the metal are arranged in regular planes. The outside of the crystal is irregular, but since the atoms are regularly arranged this does not effect its general properties.

In the majority of metals the crystals are quite small and are arranged quite irregularly with regard to one another, but in certain cases quite large crystals can be obtained. These crystals are interesting from the point of view of scientific study, but for the most part the student of metal finishing will not be concerned with them. However, a considerable amount of information concerning the properties of metal has been obtained by the study of such crystals.

If an attempt is made to deform a metal crystal by squeezing it, it will be found that the metal will change its shape. If it was possible to watch what actually happens in the crystal it would be found that the atoms in one plane tend to slip over the atoms in another. In general it is far easier to deform a piece of metal by deforming the crystals themselves in this way, than it is by moving one crystal in relation to another. It will be seen from this that if a piece of metal is composed of large crystals it will generally be softer and more easily deformed than a piece of similar metal composed of small crystals, because in the first case deformation takes place by the slip of the atomic planes of the large crystal, whereas in the second place there are a number of small crystals with the planes at all different angles and therefore the metal is much harder to deform. In general, therefore, a piece of metal composed of small crystals is harder and less malleable.

It is possible by varying the treatment by which the metal is produced, to vary the size of the crystal. Thus, if a piece of copper is melted and then cooled very slowly the metal tends to solidify in large crystals, very much as in chemistry, if a crystal is grown slowly from a saturated solution of a salt, a large crystal is obtained, whereas if it is quickly cooled from a saturated solution a small crystal is obtained. If a piece of copper is hammered, the large crystals will be broken up and a number of much smaller ones produced, and as a result the metal becomes harder and less easily deformed. If the piece of copper, after hammering, is heated to a low red heat, and then cooled it will be found that many of the small crystals will have grown at the expense of those near them and that the crystal structure is now large and more like the original and the metal itself is again softer.

Many metals have a certain amount of springiness, that is to say, if they are bent they will fly back to their original shape. This, however, only happens up to a point, depending on the type of metal in question. If a small amount of tension is put on a rod of metal and is then removed the metal will return to its original form, but if the tension or bending is increased the metal is permanently deformed. The amount which it will bend before it becomes permanently deformed is known as its elastic limit. If it can be imagined that when the metal is bent the atomic planes are being pushed over one another, it is possible to visualize the position by remembering that it will be necessary to push one plane so far before, so to speak, it comes over the top of the atom underneath and starts to fall into the cavity the other side. If it is pushed only so far that it is slightly out of its original position, when it is left alone it will tend to return to its original position, but if it is pushed a little farther, it will go from one atom to the next and take up a new position where it will remain. This is, of course, a very approximate picture of what actually happens but will serve to emphasize the way in which a metal is deformed.

When a metal is formed by electrodeposition, the atoms which are released at the cathode surface take up their position in the crystal lattice of the growing metal in a very similar manner to that in which the molecules of a salt crystallize from an aqueous solution. By varying the depositing conditions it is possible to make these atoms grow into either large or small crystals and in some

cases, even to arrange that these crystals are themselves orientated in a certain manner. In this way it is possible to vary the physical properties of the metal being deposited.

A solid piece of metal may be formed in a number of different ways. It may solidify from molten metal or it may actually solidify directly from vaporized metal (for instance, in the vacuum evaporation of aluminium). It may be deposited from an aqueous solution by electrodeposition or from fused salts by the same method. It may be formed by compressing powder which is afterwards sintered by heating. It may even be built up by a spray of vaporized metal from a metal spraying pistol. The metal produced by these various processes will vary somewhat in properties. These properties may often be changed by subsequent treatment. For example, a piece of metal which has been melted and cast into an ingot may be rolled out into a bar or sheet. The rolling process will tend to break up the crystals and elongate them in the direction of the rolling, so that if the metal so produced is examined, it would be found that it is composed of long crystals all lying in the same direction. This rolled metal will have somewhat different properties from the original cast metal, although its chemical composition is, of course, the same. As previously mentioned, if the metal is heated to a moderately high temperature, though well below its melting point, it will often recrystallize to form a softer, more easily malleable material.

Metal produced by electrodeposition may also have its structure modified by working or heat treatment. As mentioned before, however, changing the conditions of deposition may also vary the structure very materially and in some cases it is possible to produce a metal whose properties cannot be reproduced by other methods of production.

Alloys.

What has been said above applies to a pure metal, but many of the common materials are either metals of commercial purity, that is to say, containing small quantities of other metals, or alloys in which two or more metals are intentionally mixed together in order to obtain material of specific properties. In such cases crystals of more than one type may be present in the alloy.

Considering brass as an example, if the alloy contains 75 per cent copper and 25 per cent zinc, then crystals of only one type known as the alpha crystal will be present. This is actually made of a solid solution of the zinc in the copper. If, however, the amount of zinc is increased, a stage will be reached where two dis-similar types of crystals are present. This is due to the fact that after a time no more zinc can be dissolved in the alpha crystal, and a beta crystal separates, having a higher percentage of zinc in it. This is called a "two-phase alloy", and the properties of the two crystals are dis-similar both physically and chemically.

In some cases the different phases may be stable only at certain temperatures. For example, steel is an alloy of iron and carbon. If a piece of steel is heated up to near its melting point all the carbon will dissolve in the iron. If it is allowed to cool slowly, part of the carbon will separate as iron carbide and the steel will contain a small lamella of iron and iron carbide. This structure is generally known as "pearlite". If, however, the steel is again heated to a high temperature so as to get the carbon in the solution, and then it is cooled by quenching in water, the carbide will not have time to separate out and a structure composed of only one type of crystal ("austenite") is formed, this material being very much harder than the original material.

It is necessary for the steel to contain a moderately high percentage of carbon to obtain this effect, thus, if a piece of mild steel, which contains only a very small quantity of carbon is heated up and then quenched, it will not noticeably harden, but if a piece of tool steel is similarly treated, a piece of hard steel which cannot be filed, will be obtained.

Although, in the majority of cases pure metals are deposited, there are some alloys which are of importance to the electroplater (brass, tin-nickel, tin-zinc, etc.). It is still however, necessary for him to realize the general type of structure of alloys, because many of the articles which he has to plate will be composed of these alloys. Although in metal finishing generally the amount of work that has to be done to them is small, the fact that an alloy may be composed of two separate phases with slightly differing properties may effect the preparation treatment prior to plating. For example, it is practically impossible at the present time to obtain a highly polished surface by electropolishing a two-phase alloy although claims have been made in certain cases that this can be done. It is very desirable, therefore, that those concerned with the finishing of metal objects shall have a thorough knowledge of the structure and properties of the material of which these objects are composed, and the way that this material behaves when being ground, polished, or etched. The effect of the conditions of deposition on the structure of properties of metals will be dealt with in greater detail later.

Elementary Electro-Chemistry

Both metals and solutions of metallic salts will conduct electricity, but the mechanism by which they do so is quite different. In a piece of solid

metal the electric current is composed of a stream of electrons which pass through the metal from atom to atom. An atom is composed of a positive charge around which a number of negative charges, electrons, circulate. When a potential difference is applied to two points on a piece of metal the electrons tend to pass along the metal. It must not be imagined, of course, that every electron in the metal immediately proceeds in the same direction. Actually, these electrons are spinning round the central positive charges of the atoms in a particular manner which can, up to a point, be calculated. What happens is that under the conditions described, some electrons tend to move rather more in one direction than another, and so in the aggregate form a stream. The electron is a unit of negative electricity and therefore moves, in the external circuit, from the negative to the positive pole. This motion of the electrons does not in any way effect the metal itself, because when the motion is stopped by removing the potential difference between the two points, the metal reverts to its original state.

In the case of an electrolytic cell, the position is somewhat different. If, into a solution of copper sulphate is inserted two copper plates and then the potential difference is applied between these two plates, the electrons will pass down the copper composing the negative electrode, or cathode, of the cell, and collect at the interface between the copper and the solution. Here they will meet a number of positive copper ions, that is copper atoms having a positive charge, or, in fact, lacking two electrons. These copper ions will be attracted to the surface of the cathode where they will gain two electrons and become copper atoms. At the same time, assuming the copper salt to be copper sulphate, the like number of sulphate ions composed of an atom of sulphur and four atoms of oxygen and each having two electrons in addition to the normal number present, will be correspondingly released at the anode, giving up their two electrons which now proceed up the copper anode. In fact, therefore, a stream of electrons is produced through the whole system, but their progress through the solution is accompanied by the movement of matter, that is to say, the copper atoms are deposited on the cathode, whereas the sulphate group is liberated at the anode where it will react with the copper present to reform copper sulphate.

When a salt such as copper sulphate is dissolved in water, it ionizes or breaks in half to form charged copper ions and sulphate ions. A copper ion is an atom of copper lacking two of its outer electrons, while the sulphate ion is a group of atoms containing one sulphur and four oxygen atoms, containing two additional electrons. It is usual to say, therefore, that the copper ions are positively charged and the sulphate ions, negatively charged. It is possible that both these ions have a water envelope but this need not be considered here.

It is essential that the student should realize the basic differences between these two methods of conduction. In the metal, the electron proceeds by passing from one atom to another, while in the solution it proceeds in effect by getting on to a charged atom and carrying itself in this way across the solution. Of course, this is actually a consummation of the movement of a very large number of electrons. Although the charged ions do move slowly under the influence of an applied potential, their movement from this cause is quite slow and it would take an ion some weeks to progress across a normal plating tank if it moved by migration alone. The ions, however, also move by diffusion and so if a number of copper ions is taken from that part of the solution immediately adjacent to the cathode, further ions will tend to diffuse into this area. Since the number of positive and negative ions must balance when the positive ions are taken from the solution, a like quantity of negative ions must also be released at the opposite electrode, otherwise a potentional would build up which would quickly neutralize the applied potential difference and stop the action.

It will be seen that if a current is passed through an electrolyte, matter will be displaced, and some type of action will be obtained. This may take the form of a deposit of metal at one of the electrodes, and a solution of the opposite electrode, or the release of gas at one or both of the electrodes, or possibly of some chemical change in the solution. It is, however, quite impossible to pass an electric current through an electrolyte without causing some change.

Faraday's Laws.

Faraday discovered that the amount of the change produced by passing a current through an electrolyte was proportional to the amount of the current that was passed. He enunciated two laws which are so important to the electrodepositer that it is advisable for a candidate for the examination to learn these by heart and also to understand thoroughly their significance. These are as follows:

1. "*The chemical effect resulting from electrolysis is directly proportional to the quantity of electricity which is passed through the electrolyte.*"

For example, if a certain quantity of electricity is passed through a solution of copper sulphate, that is to say a number of ampères for a stated time, a certain weight of copper will be deposited on the cathode of the cell. If the same number of ampères are passed through for double the time,

that is to say, double the amount of electricity, double the amount of copper will be deposited. Alternately, if twice the number of ampères are passed through for the same time, again double the amount of copper will be deposited. The quantity of electricity is a unit involving the amount of current passed and the time, the normal unit is a coulomb, which is the quantity of electricity passing in a second, with a mean current of one ampère. For practical purposes, however, ampère-hour is often used.

2. "*The quantity of each substance chemically changed or liberated at an electrode by the passage of a definite quantity of electricity, is directly proportional to the equivalent weight of the substance.*"

This means, in fact, that if the equivalent weight of the metal or gas is known and also the number of coulombs which have been passed through the solution, it is possible to calculate the actual weight of material which will be obtained. In point of fact, Faraday found that 96,540 coulombs released or changed one equivalent weight in grammes of the substance concerned. This law is extremely important because it allows the calculation of the weight, and therefore the thickness, of the metal deposited. In applying it, however, it must be remembered that all the current may not be concerned with the deposition of the particular metal which is being dealt with. For example, when chromium is deposited from a chromic-acid solution, not only metallic chromium but also a large quantity of hydrogen is released, so that at the cathode the amount of current actually depositing the chromium is only something of the order of about 10 to 15 per cent of the total. The relation between the amount of current carrying out the required process to the total current put through the cell, is generally known as the current efficiency of the process. While for many deposition processes this may be quite high there will be some, for example, the one stated, in which it is comparatively low and since it may vary quite considerably with conditions of deposition, the calculations that are made in such a case will be somewhat approximate. It must also be remembered that the equivalent weight of a metal is its atomic weight divided by its valency. If a monovalent ion is being considered, for example, in the deposition of copper from a cyanide solution where copper is in the cuprous state, twice the weight of copper for a given quantity of current will be obtained, as compared with a divalent ion, for example, a solution of cupric sulphate. However, twice the amount will be obtained only if the current efficiencies in both cases are the same, but in some cases the efficient of a copper-cyanide solution may be considerably lower. Although it is possible to obtain more copper per ampère-hour from a cyanide solution, this does not necessarily mean that more is obtained for a given amount of power, because the copper-cyanide solution requires a relatively higher voltage so that the amount of copper per watt hour of input is in fact, generally lower.

Coulometer.

This apparatus is in fact, a small electrolytic cell designed to measure the total amount of current passed through it by estimating the amount of the products produced. In some cases these may be metal, for example in the silver or copper coulometer where the amount of metal deposited can be weighed and from this the amount of current calculated. In other cases the current is utilized to liberate a gas, for example, hydrogen, at the cathode or a mixture of oxygen and hydrogen for both electrodes, This gas can then be measured and its weight calculated and from this the current assessed.

It is obvious that the current efficiency of the process employed must be as near 100 per cent as possible, and the cell must be arranged so that the products of the electrolysis can be accurately measured. The cells are generally arranged to work at relatively low current densities and the electrodes are basically light so that changes of weight can be easily estimated.

For practical purposes the copper coulometer is generally used in the laboratory. This is composed of two pieces of copper in a solution of acid copper sulphate, the cathode being generally a piece of sheet or gauze. The cathode is carefully cleaned, dried and weighed and then inserted into the cell, which is put in circuit with the apparatus through which the quantity of current is required to be measured. At the conclusion of the process the cathode is removed from the cell, carefully washed off, dried and again weighed. The cells should be of such dimensions that the current density is relatively low, about 2 to 3 amp. per square foot. From the weight of copper deposited, the number of coulombs passing through the cell can be calculated.

As mentioned before, it is essential that the candidate for the Intermediate examination should understand and be in a position to quote Faraday's Laws. It is quite possible also, that the question may include a description of a coulometer and the purpose for which it is used.

Anodic and Cathodic Processes.

The anode has been defined as the electrode by which the current enters the electrolytic cell, but it is perhaps better to remember that it is the electrode by which the electrons leave the cell. The cathode is, therefore, the electrode by which

(*Continued in page* 182)

A Students Guide to Examination Courses in Metal Finishing

(*Continued from page* 181)

the electrons enter the cell. It may appear somewhat confusing to the student that the electrons should actually proceed in the opposite direction to the conventional direction of the current. Unfortunately, when this was originally put forward the electron had not been discovered. In order, therefore, to explain the fact that the electron travels in the opposite direction, the electron was defined as a unit of *negative* electricity.

At the cathode the electrons enter the solution. This means that they are releasing ions which are lacking in electrons, that is to say, positively charged ions. The majority of metal ions in the solution are positively charged and so, also, is the hydrogen ion which is the smallest and most quickly moving ion. Thus not only will there be a tendency for metals to be deposited on the cathode, but there will also be a strong tendency for hydrogen to be released. The various ions are normally liberated in the order of their position in the electrochemical series, that is to say, a copper ion will tend to be liberated before a hydrogen ion, and a hydrogen ion before a nickel or zinc ion. For various reasons, however, this order does not always apply but in the majority of cases a certain amount of hydrogen will tend to be liberated at the cathode. This will produce an alkaline condition at the cathode. Since hydrogen ions are being taken from the cathode layer, there is also a tendency for the solution adjacent to the cathode to have a lower concentration of hydrogen ions than the bulk of the solution, which means, in fact, that it will be less acid. Thus the reactions of the cathode will tend to produce a reducing condition and also will tend towards alkalinity.

At the anode exactly the opposite condition will prevail, oxygen will tend to be liberated and the layer of solution adjacent to the anode will become acid so that there is a tendency to oxidize the anode itself, or in some cases substances in solution adjacent to it. In many cases also, the acid condition produced will dissolve the materials of which the anode is composed.

In certain processes these various conditions may be of advantage, for example, chemicals may be oxidized or reduced electrolytically. The anode material itself may also be oxidized, for example, in the case of aluminium an adherent oxide layer is formed by making it the anode in a suitable solution. Reducing conditions may be of advantage when removing grease or other foreign matter from a metal surface, and also for reducing thin oxide layers. (*Series to be continued*)

"HOT DIP GALVANIZING, 1954"

Proceedings of the Third International Conference on Hot Dip Galvanizing

The Third International Conference on Hot-Dip Galvanizing organized by the Hot Dip Galvanizers Association in collaboration with The Zinc Development Association, was held in Oxford in July, 1954. To this Conference seventeen papers were presented by authors from most of the countries in Europe and the U.S.A., and were fully discussed.

A report of the Conference containing abstracts of these papers and a verbatim report of the discussion, was published at the time in the technical press[1], and now the full text of the papers with the discussions incorporating authors revisions and written contributions submitted subsequent to the Conference, has been published as an official volume of Proceedings by the Zinc Development Association under the title "Hot-Dip Galvanizing 1954."

This volume goes to 280 pages, bearing over 130 illustrations and an unusual feature in a work of this kind is that 19 of the illustrations are in full colour.

Although much of what is said at a Conference of this nature is ephemeral, nevertheless the book contains a great deal of information of permanent interest to all those associated with the galvanizing process and its value in this respect is enhanced by the inclusion of a satisfactory index.

A special feature of this publication is that particular care has been taken in editing it to ensure that the material available is presented in a logical manner whereby certain papers have been brought together in the chapters, where appropriate, and considerable re-arrangement of the discussions has been carried out.

The first chapter entitled "Galvanizing Survey" contains a paper by R. L. Stubbs, director of the Zinc Development Association which surveys recent progress in galvanizing and gives statistical information on the industry.

Of particular technical interest in the second chapter is the description by Mr. Nelson Cook, of the new Cook-Norteman process in which electric induction heating is used and a close positive control of coating adhesion is possible.

Subsequent chapters are devoted to contributions on sheet galvanizing, tube galvanizing, wire galvanizing, the galvanizing of threaded parts, work costing, bath heating, dross formation, inspection, after-treatment, and incentives.

Priced at 2 guineas, post free, the book is obtainable through booksellers or direct from the Zinc Development Association.

[1] *Sheet Metal Industries*, 1954, *August* 31, (328), *p.*645

FINISHING

NEWS REVIEW

METALLURGY IN RELATION TO ELECTRODEPOSITION

New Course at Birmingham University

A course designed to provide a working knowledge of those principles and techniques of metallurgy which have a bearing on the properties of electrodeposits has been announced by the Department of Industrial Metallurgy of the University of Birmingham where three years ago the Joseph Lucas Research Fellowship was established for the purpose of initiating research on the properties of electrodeposits. Industrial sponsorship of this research is evidence of an increasing interest in the physical, mechanical and metallurgical properties of electrodeposits. The study of electrometallurgy has now become an integral part of the Department's activities and it is believed that a useful service can be offered to the plating industry by giving a course of metallurgy designed especially for electrodepositors.

Enquiries within industry have shown that such a course would be favourably received and sufficient support to launch the course has already been secured. In view of this reponse it has already been decided to hold the first course in the Autumn of 1955. It will be given on a part-time basis of two whole days a week for ten consecutive weeks. This arrangement should enable those taking the course to remain in contact with their normal work in industry.

The course has been designed on the assumption that all those attending will have a good general knowledge of science, but that they are unlikely to have had any systematic training in metallurgy and in metallurgical methods of investigation. Both lectures and practical work will be arranged.

It is assumed that a high proportion of the students will be men of some technical experience; a series of conferences and seminars will therefore be arranged to encourage students to share in and criticise each other's specialized technical knowledge and experience. Demonstrations of specialized equipment for the testing of electrodeposits will be arranged with the manufacturers.

It is intended to give students as much individual attention as possible during practical work; for this reason it will be necessary to restrict the course to a maximum of twelve students.

It is not anticipated that the course will be repeated annually, but this decision may be reviewed later if there is a sufficient demand from industry.

Syllabus

The following subjects will be dealt with during the course:

1. Metallography.
2. Metallurgy of the important industrial metals and alloys.
3. Crystallography.
4. X-ray diffraction.
5. Metallurgical methods of investigation (microscopy, microhardness testing, photomicrography, modern optical techniques, radiography, microradiography, etc.).
6. The physical and mechanical properties of electrodeposits (including methods of testing).
7. The structure and growth of electrodeposits.
8. Alloy deposition.
9. Seminars.

The first three of these subjects are intended to give students a background knowledge of metallurgy. The amount of time to be devoted to the first of these will only be decided when candidates for the course have been interviewed and their present knowledge assessed.

Lecture courses in subjects 4 and 5 will be taken in conjunction with students of an existing postgraduate course in Metallurgy. Practical work will, however, be especially arranged to deal with the techniques likely to be of most importance in the study of electrodeposits. Published work on the growth and on the physical and mechanical properties of electrodeposits will be reviewed and discussed in the lectures of subjects 6 to 8. An endeavour will be made to arrange a few lectures on these subjects by specialists from industry.

Each student will be asked to prepare a paper on a topic relevant to the course for presentation and discussion at an informal seminar.

The course will commence during the first week of October and will be given on two whole days per week during the subsequent ten weeks. The mornings will be devoted to lectures, the afternoons to practical work and seminars.

Candidates will be required either to hold a degree or to possess other qualifications or suitable experience which will ensure that they will be able to benefit from a course given at degree level.

The fee for the course, including lectures and laboratory work, has been provisionally fixed at fifteen guineas.

Further information on the course may be obtained from The Secretary, Department of Industrial Metallurgy, The University of Birmingham, Edgbaston, Birmingham, 15.

Administrative Reorganization of EFCO Group

BY the terms of a resolution adopted at a meeting of the Electric Furnace Co., Ltd., Weybridge, Surrey, on April 1, the EFCO Group of Companies has been reorganized in the form of a holding company and four subsidiary companies.

The holding company will be known as EFCO Ltd., and will provide general administrative services for the other companies of the Group.

Electric Furnace Co., Ltd., will become a subsidiary company, but will continue to design and manufacture the same range of products as before.

The remaining subsidiaries, Electric Resistance Furnace Co. Ltd., Electro-Chemical Engineering Co. Ltd., and EFCO-Industrieofen, A.G., will not be affected by the reorganization.

DUTY ON LIGHT HYDROCARBON OILS

Representations to Chancellor

SEEKING the removal of the duty on light hydrocarbon oils used for industrial processes, a deputation from the Industrial Light Oils Committee, representing 16 trade associations, saw Mr. R. Maudling, Economic Secretary to the Treasury, recently.

Mr. Norman Campbell, director of the National Paint Federation and chairman of the committee, made the following points when he submitted the case for the repeal of the duty.

(1) That it was fundamentally unsound and wrong in principle to tax the essential raw materials of industry; (2) That in other industrial countries there was either no tax whatever on light hydrocarbon oils used for industrial processes or substantial rebates in tax were allowed; (3) That the U.K. tax, which had been raised over the years from 4d. to 2s. 6d. per gallon, was now equal to 125 per cent of the price of the raw material itself. That compares with a maximum purchase tax of 75 per cent on the most luxury type of goods.

After discussion the Economic Secretary informed the deputation that he would report fully on the matter to the Chancellor.

JENOLITE EXHIBITS AT UTRECHT TRADE FAIR

AT this year's Utrecht Trade Fair, held from March 22 to 31, several well-known Jenolite metal pre-treatment and anti-corrosion processes were exhibited by Jenolite's Netherlands associates, N.V. Technisch Handelskantoor, J. D. Broekman, of The Hague. One of the Company's experts on marine corrosion, Mr. J. S. Armstrong, flew out from Tyneside for the duration of the Fair to deal with technical queries; while Mr. J. H. Lawrence, Managing Director of Jenolite Ltd., visited the stand at the conclusion of the Fair.

The decision to exhibit this year reflects the rapidly growing interest in the Netherlands in methods of combating corrosion, particularly in the building and shipping industries and in armed forces defence equipment.

LIGHT-ALLOY SHEET FINISHING

SINCE the experimental unpainted finish for the exterior of light-alloy railway carriages was initiated by London Transport Executive, increased interest has been aroused in this application of unprotected aluminium sheet.

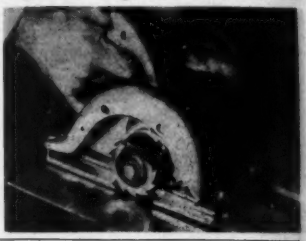
To provide a neat clean finish, a method has been evolved by the Aluminium Development Association by using a modified Black & Decker 6-in. heavy-duty portable electric saw to remove the projecting beads from welded light-alloy sheets so that a flush surface is provided.

The saw was modified by mounting a milling cutter measuring 2¾ inches in diameter by ⅛ inches in width on the blade shaft, and by removing the lower blade guard and fitting in place an adjustable guide plate of teak or other hard wood as shown on the right. A non-metallic material is required so that scratching of the light-alloy sheeting does not occur.

The cutter speed for this application is between 2-3,000 feet per minute, and in use the guide plate is adjusted so that approximately .001 to .005 in. of metal is left upstanding after the bead has been cut down. The remainder of the projection can then be removed with a disc sander.

After the weld beads have been removed, it has also been found that a Black & Decker No. 44 Orbital Sander produces an excellent overall effect to the unpainted alloy surfaces by giving a mechanically produced, scratched finish which possesses a sufficient degree of reflectivity and metallic lustre to overcome the patchiness which can occur in service with a full matt surface finish. Also accidental scratches and marks do not show up readily.

The railway vehicles on which these two machines were used were for the New Toronto Subway, the builders being the Gloucester Carriage and Wagon Co. Ltd.



Government Research on Corrosion

REPLYING to Mr. Dodds, who asked the Parliamentary Secretary to the Ministry of Works, as representing the Lord President of the Council, on what date Government-sponsored research into the problems of corrosion commenced, and what progress had been made in a matter that was of economic importance, Mr. Bevins said that investigations by the Admiralty into the causes of corrosion began sometime in the 17th century and had continued ever since. Organized research by other Government departments was of comparatively recent origin.

The Ministry of Supply was carrying on work started at Woolwich during the first world war; organized research sponsored by the Department of Scientific and Industrial Research started in 1921; and the Post Office has been engaged on it for at least 25 years. Much progress had been made towards a full understanding of the causes of corrosion and in devising methods of prevention. These methods were being applied both by Government departments and by industry.

CHEMICAL MERGER

Bowmans Chemicals Ltd. of Widnes have announced that negotiations with Howards and Sons Ltd., of Ilford, which have been in progress for a considerable time, have now been concluded for a substantial measure of closer working between the two companies.

The arrangements which are being put into force immediately involve a long-term working agreement with Howards of Ilford Ltd. and the appointment of two representatives of Howards, Mr. J. A. E. Howard and Mr. G. C. H. Clark, to the board of Bowmans and the subscription by Howards and Sons Ltd. of 62,500 Ordinary Shares of 4*s*. each of Bowmans.

Change of Address

AT the beginning of April the Sales Division of The Aerograph Co., Ltd., manufacturers of DeVilbiss Aerograph Spray Painting equipment and the Aerograph Air Brush, moved into new offices in the same premises as the DeVilbiss Aerograph Showrooms at 47, Holborn Viaduct, London, E.C.1.

The factory and head office remain at Lower Sydenham, but sales and technical enquiries will be exclusively handled at Holborn Viaduct. The central location of the new offices will assure even better service and attention to customers while the existence of a spacious showroom attached to the office will prove of added interest to all engaged in product finishing.

THE INSTITUTE OF METAL FINISHING

Annual Conference May 17-21, 1955 at the Palace Hotel, Torquay

THE Annual Conference of the Institute of Metal Finishing will be centred this year from May 17-21 at the Palace Hotel, Torquay, at which the greater number of the delegates will be resident, and where all technical sessions will be held.

The Annual Conference of the Institute, which, since the War, has been held regularly in the Spring at a seaside or similar resort, has commanded, growing support from members of the Institute and others in the metal finishing industry. Last year the Institute was responsible for the organization of the fourth International Conference on Electrodeposition and Metal Finishing in London, at which nearly six hundred delegates and their ladies were present. This year marks a return to the normal run of Spring Conferences, but it can be expected that many of those who were present last year at the International Conference will seek to renew their associations with the members of the Institute by participating in the activities at Torquay.

In addition to some fourteen papers presented at six technical sessions, careful arrangements have been made to cover the interests of ladies attending the Conference and to provide the social occasions, which form so valuable a feature of this type of meeting. The detailed programme is set out below and is available, together with application forms for Conference reservations, from the Conference Secretary, Institute of Metal Finishing, 32, Great Ormond Street, London, W.C.1. Hotel accommodation is limited and early application is urged on all those wishing to participate.

PROGRAMME

TUESDAY 17th MAY 1955

PALACE HOTEL

7.30 p.m. Informal Dinner.
9.00 p.m.—10.30 p.m. Film Show.

WEDNESDAY 18th MAY 1955

PALACE HOTEL

9.15 a.m. Conference opened by the Deputy Mayor of Torquay.
9.30 a.m.—12.30 p.m.

1ST TECHNICAL SESSION

1. "The Effect of Chromium Plating on the Fatigue Strength of Steel"

By C. Williams, B.Sc., A.I.M., and R. A. F. Hammond, B.Sc., A.R.C.S. F.R.I.C.

2. "A Study of Cracking in Chromium Deposits"

By H. Fry, B.Sc.

3. "A New Method of Analysing the Stresses and Strains in Deposited Coatings"

By J. J. Pick, Ph.D.

1.00 p.m. Luncheon.
2.30 p.m.—4.30 p.m.

2ND TECHNICAL SESSION

4. "The Electrodeposition of Iron-Zinc Alloys"

By S. Jepson (Miss), S. Meecham, M.Sc., and F. W. Salt, Ph.D., B.Sc.

5. "On the Electrodeposition of Tungsten-Cobalt Alloys from Aqueous Solutions"

By T. P. Hoar, M.A., Ph.D., B.Sc., F.R.I.C., F.I.M., and I. A. Bucklow, B.A.

6. "Corrosion Tests of Electrodeposited Tin-Cadmium Coatings on Steel"

By S. C. Britton, M.A., and R. W. de Vere Stacpoole.

PALACE HOTEL

7.30 p.m. Informal Dinner.

SPA BALLROOM

8.30 p.m.—11.00 p.m. Reception and Dance, by invitation of the Mayor and Corporation of Torquay.

THURSDAY, 19th MAY 1955

PALACE HOTEL

9.30 a.m.—12.30 p.m.

3RD TECHNICAL SESSION

7. "The Chemical Polishing of Mild Steel by Hydrogen Peroxide-Oxalic Acid Mixtures"

By A. Hickling, D.Sc., Ph.D., F.R.I.C. and A. J. Rostron, B.Sc.

8. "The Electrolytic Oxidation of Copper and Copper Alloys in Hot Alkaline Solution"

By S. G. Clarke, D.Sc., A.R.I.C., F.I.M., and J. F. Andrew, B.Sc.

9. "The Structure and Growth of Electrodeposits, and the Modifications caused by Brightening Agents"

By H. Wilman, D.Sc., Ph.D., F.Inst.P.

1.00 p.m. Luncheon.
2.00 p.m. Torquay Golf Club. John Preston Golf Trophy Competition.
2.30 p.m. Coaches leave Palace Hotel for trip on River Dart to Totnes.
6.30 p.m. Arrive back Palace Hotel.
2.30 p.m. Coaches leave for Works Visit.
6.30 p.m. Arrive back Palace Hotel.
7.30 p.m. Informal Dinner, Palace Hotel.

FRIDAY 20th MAY 1955

PALACE HOTEL

9.30 p.m.—12.30 p.m.

4TH TECHNICAL SESSION

10. "The Barrel Plating of Screw Threads"

By A. W. Wallbank, B.Sc., F.R.I.C. and D. N. Layton, Ph.D., M.Sc., A.R.C.S.

11. "Electroforming in Electronic Engineering"

By P. M. Walker, A.U.C.N., N. Bentley and L. E. Hall, B.Sc., A.C.G.I.

1.00 p.m. Assemble for Photograph, Palace Hotel.
1.15 p.m. Luncheon.
2.30 p.m.—4.30 p.m.

5TH TECHNICAL SESSION

12. "The Electron Microscope in the Study of Paint"

By N. D. P. Smith, B.Sc., A.Inst.P.

13. "The Blistering of Paint Films on Steel Surfaces"

By A. Nicholson and H. A. H. Jenkins.

PALACE HOTEL

7.00 p.m.—7.30 p.m. Reception by the President and Mayor of Torquay.
7.30 p.m.—1.00 a.m. Banquet and Ball

SATURDAY 21st MAY 1955

PALACE HOTEL

9.30 a.m.—12.0 noon

6TH TECHNICAL SESSION

14. "Metal Finishing—Technique or Technology"

By the Right Hon. the Earl of Halsbury, F.R.I.C., F.Inst.P.

introducing

Discussion on "Education for the Metal Finishing Industry."

Conference ends.

Meetings of the Month

April 18

Institute of Metal Finishing (London Branch and Organic Finishing Group). "Electrostatic Painting Processes" by R. Tilney, A.M.I.Mech.E. followed by film, at the Northampton Polytechnic, St. John Street, London, E.C.1. 6.15 p.m.

April 21

Institute of Vitreous Enamellers (Northern Section). "Heat-resistant Coatings" by B. Zick.

April 27

Society of Chemical Industry (Corrosion Group). Annual General Meeting and Chairman's Address, at the Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

April 29

Institute of Vitreous Enamellers (Southern Section). Annual Dinner and Theatre Visit.

Institute of Metal Finishing (Sheffield and N.E. Branch). Paper on subject to be announced at the Grand Hotel, Sheffield. 6.30 p.m.

May 4

Institute of Metal Finishing (Scottish Branch). Annual General Meeting followed by paper on "Phosphating" by S. J. Scouse at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow. 7 p.m.

May 5

Institute of Vitreous Enamellers (Midland Section). Annual General Meeting followed by paper "Safety in the Mill Room" by Miss K. Crundwell at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2. 7.30 p.m.

Institute of Metal Finishing (N.W. Branch). Annual General Meeting followed by Platers Forum at the Engineers' Club, Manchester. 7.30p.m.

May 11

Society of Chemical Industry (Corrosion Group). Visit to the works of G. A. Harvey and Co. Ltd., Greenwich. 2.30 p.m.

May 17—21

Institute of Metal Finishing. ANNUAL CONFERENCE, Palace Hotel, Torquay.

May 19, 20

Institute of Vitreous Enamellers. SPRING MEETING, Porthcawl.

TRADE and TECHNICAL PUBLICATIONS

Heat Treatment: The circumstances of war brought about the cessation of publication of the Wild-Barfield Heat-Treatment Journal, which had for some years previously circulated to metallurgists and others interested. Since the end of hostilities, the Wild-Barfield Heat-Treaters' Diary has been introduced, and has proved very popular. The inclusion of Abstracts from technical journals and the like, and of technical articles is obviously impracticable in such a publication, so the decision to re-issue the Wild Barfield Heat-Treatment Journal has been taken. The first of the new series, has been numbered Volume V. No. 34.

Zinc and Its Alloys: Volume 13, No. 1 of Z.D.A. Abstracts contains many items of current interest relating to zinc and its alloys. The abstracts in this issue cover such subjects as hot-dip galvanizing, zinc plating, sprayed zinc coatings, paints and pigments, zinc oxide, cadmium, soldering and welding, corrosion and cathodic protection, etc. Also published by the Zinc Development Association is an index to the abstracts published during 1954.

Furnaces: Five leaflets have been received from G. W. B. Furnaces Ltd., Dudley, covering some of the continuous electric resistance furnaces manufactured by the company. The types described and illustrated are those of the wire and strip pull-through, rotary hearth and vertical conveyor, mesh belt, walking beam, and chain and slat.

Conveyor System: The "Stanrun" overhead chain conveyor is manufactured by George W. King Ltd., Stevenage and Hitchin, Herts. With this conveyor system each operator automatically has a steady supply of components at a correct working position. This means no waste movement, idle time, or handling personnel.

The operator reloads the component on the same trolley from which it was removed, so work is maintained in correct sequence. Work movement is thus accurately controlled and progress and loading control minimized. All work is off the floor so less working space is required and risk of damage minimised. The flexibility of the conveyor enables it to be routed to suit complicated process layouts and different floor levels. Trolleys may be transferred from one conveyor to another and arrangements can be made so that only loaded or, if required, unloaded trolleys be transferred, or specially selected trolleys. The transfer keys on the trolley enable it to be routed to hundreds of different destinations. The system is fully described in a brochure which is available from the company.

Dust-control Units: A leaflet received from Dallow Lambert and Co. Ltd., Spalding Street, Leicester, announces that the company's unit dust collectors of the fabric-pad type can now be fitted with an automatic shaker. This device set to work at predetermined intervals will ensure thorough shaking of the filter medium, where previously it had to be shaken by hand.

Furnace and Stove Insulation: "Therbloc" for furnace and stove insulation is manufactured by Stillite Products Ltd., 15, Whitehall, London, S.W.1. Although it can be used without other refractory materials it is primarily intended as a backing to conventional insulating bricks where it ensures maximum economy on account of its relatively low thermal conductivity. "Therbloc" is a light-weight insulating slab of resilient texture with high insulating properties and it can be cut easily and cleanly with a sharp knife. In addition to its value as a thermal insulator, "Therbloc" has a very marked effect in reducing noise from furnaces.

Fans and Air-Blast Equipment: Two new booklets have been published recently by Keith Blackman Ltd., describing certain of the company's products.

Publication No. 32 deals with the Tornado range of APA propeller-type fans which are now available in diameters from 18 to 48 in. Particular features of this three-bladed fan are its high volumetric capacity, no overloading characteristics, high operational efficiency, quietness in operation, strength and rigidity.

Publication No. G.1 entitled "Air Blast Equipment" is the first of a new series of quarto-size catalogues dealing with the K.B. range of industrial gas equipment. It covers the Type 3 mixture controller, zero governor, air blast injectors and burners.

Aluminium Sign: The current issue of Aluminium Courier, published by the Aluminium Development Association contains an illustration of an advertising sign for a well known brand of whisky, which is 13 ft. high and painted in full colour. The text points out that provided correct pretreatment is given to the aluminium surface the paint adheres firmly and as oxidation is not progressive there is no peeling or blistering. Further, should the paint film be damaged, corrosion is limited to the exposed area of the metal and does not spread under the surrounding paint nor does it cause any discoloration.

NEW RECORDS SET UP IN NICKEL DELIVERIES

NEW records were established in 1954 by the International Nickel Company of Canada, Limited, for net earnings, deliveries of nickel to the free world, and ore mined. Net earnings of the company and its subsidiaries were 65,295,186 dollars, in terms of US currency.

Deliveries of nickel attained a record total of 282,000,483 lb., an increase of 30,582,711 lb. over the 251,417,772 lb. delivered to the free world in 1953. For the first time in the company's history, more than 14,000,000 tons of ore were mined.

Over the course of the past five years of capacity production, International Nickel added 72,834,149 tons to ore reserves, thus not only making up the 63,020,286 tons mined during the period but also providing a net addition of 9,813,863 tons. In the Mystery Lake area of Manitoba, the report states, the "company is investigating what may prove to be an important source of nickel-bearing ore adjacent to Moak Lake. Extensive surface drilling has been carried on, and, in order to obtain additional information on the nature of the deposit, as well as the underground conditions and geology of that area, a programme of underground exploration and drilling is being undertaken" at an estimated cost of 2,000,000 dollars.

"The company has been engaged," the report says, "in a continuous programme to develop methods and equipment for airborne electro-magnetic surveying."

Underground development in the operating mines reached a total of 1,981,873 ft., or 375 miles. Construction was speeded on the 16,000,000-dollar pyrrhotite plant unit for the recovery of iron ore, analyzing about 68 per cent iron. Operations are expected to begin late in 1955.

The chairman, Dr. John F. Thompson, and the president, Mr. Henry S. Wingate, state that they expect that during 1955 industrial demand for nickel will continue at a high level and that the company will operate its mines and plants at full capacity. Decreases in defence requirements for nickel will probably be offset by large civilian demand, but they are hopeful that additional free-world nickel supplies will be available for civilian use.

HUNGARY TO PRESS EXPORTS OF BENTONITE

THE big export possibilities of Hungarian bentonite are stressed in an article in the Hungarian periodical "Nature and Society."

Hungary is rich in bentonite, a mineral of great importance as a binding agent in many industries, including iron-founding, ceramics, vitreous enamelling, constructional-engineering, rubber and linoleum making, dyeing, manufacturing fire-resistant materials, and for soil-improvement.

The article claims the montmorillon constituent of Hungarian bentonite gives a binding capacity and compressive strength superior to the American variety.

Bentonite from Hungary's Istenmezeje region has been found particularly suitable for making granular fuller's earth, which is valuable as a filtration medium. A new branch of industry in Hungary is the production of organophile bentonite, valuable for preventing sedimentation of dye and lacquer pigments.

COLLEGE OF CERAMICS Foundation Stone Laid

THE foundation stone has been laid of the new College of Ceramics, which forms the first part of the £1,000,000 extension scheme of the North Staffordshire Technical College, Stoke-on-Trent. The college will cost £200,000 and it is estimated that perimeter extensions, which will mainly be used for engineering, will cost a further £249,000.

Change of Telephone Number

FERRAMIC Industries Ltd., Hydeway, Welwyn Garden City, Herts., announce that their telephone number is now: WELWYN GARDEN 4355 (3 lines).

REORGANIZATION AT FLEETWOOD PAINTS

IT is learned that Mr. James Bonser, who recently acquired a block of the shares of Fleetwood Paints, holds "well over 50 per cent" of the £56,500 capital. He acquired the holding of the chairman, Mr. N. M. Johnston, which amounts to just under 50 per cent of the capital, and has acquired a number of shares from other sources.

Mr. Bonser has become managing director of the company, succeeding Mr. Johnston who will, however, continue as chairman.

It is stated by Fleetwood Paints that Mr. Bonser will carry out an immediate reorganization of the company.

OPENING OF BATTELLE LABORATORY AT GENEVA

THE purpose of research is to liberate man by reducing his labours, declared Monsieur Denis de Rougemont, author, and director of the European Cultural Centre, when he spoke during the formal opening of Battelle's Geneva Laboratory. He described research as a spiritual passion and urged that research institutes work in the creative spirit.

The 300 guests at the ceremony, who had previously been welcomed by Dr. Clyde Williams, president and director of the Institute, also heard Professor G. Colonnetti, president of the Italian National Research Council. He spoke of the benefits to be derived in future years from the peaceful applications of nuclear energy. He pointed out that the trouble with machines is not that they cause unemployment, but that men have been forced to serve them; in the future, however, there is hope that man may be freed from this physical drudgery. Professor Colonnetti concluded by expressing doubt as to the value of research if the results are applied without concern for their effect on society.

A third speaker, Professor L. Jacque, Professor of Chemistry at the Ecole Polytechnique in Paris, reviewed the participation of French scientists in important world technical developments. He also discussed the contributions of various research institutions to the advancement of science and technology, and he referred especially to services that organizations such as Battelle can render.

The newly-opened laboratory building is situated on a 22-acre plot in Carouge, a suburb of Geneva. The three stories and basement have a total area of 40,000 square feet and include a pilot-plant laboratory. The main building is supplemented by a villa, which houses the administrative offices and library, and a second building which contains shops. The staff of 85 is carrying on research in the fields of physics, chemistry, and metallurgy.

Latest Developments in PLANT, PROCESSES and EQUIPMENT

Hammer Finish for Electrostatic Spraying

THE application of hammer-finish type paints, or indeed any type of finish containing aluminium, by the No. 2 electrostatic spray system has hitherto been regarded as impossible of satisfactory achievement. Considerable interest therefore can be expected to be taken in the announcement by Mander Bros. Ltd., St. John Street, Wolverhampton, of the development by their laboratories of the new "Scintilla" stoving hammer finish. It is claimed for this new finish that it can be applied with the No. 2 Ransburg equipment without any difficulty, giving the usual advantages attendant upon this process over hand spraying *viz.:* full automation, uniformity of film thickness, adequate wrap-round, even patterning, avoidance of overspray, and complete coverage of complex shapes.

The development of this finish has necessarily involved the striking of a satisfactory balance between the requirements of the spray system and the film conditions necessary to ensure the development of a good hammer.

Not unnaturally therefore, some slight modifications of standard spraying technique are required to produce the desired type of finish but these are of a straightforward nature and results achieved in production using this material appear fully to bear out the manufacturers' claims. The manufacturers offer full technical details of this new paint to anyone interested in its application, together with the services of their technical personnel who have pioneered its use.

Two-Way Control Valve

A PROBLEM frequently encountered in the control of bulk material handling is the difficulty of diverting the flow of material from one duct to another. Following their policy of progressively improving design, Dallow Lambert and Co. Ltd., of Leicester, have recently introduced a modified two-way control valve for use in dust control systems.

Fig. 1 shows the new device which is identified as the K.C. Two-Way Control Valve operating on a typical bagging system. It can be used with all types of dusts, powders, chippings, wood waste, etc., and will operate fitted in any position. Basically the device consists of a "Y" piece containing a metal chute which can be pivoted to direct the flow of gas and material as required.

The profile of the chute has been designed to present minimum resistance to the flow, the flow path through the valve being smooth and regular; this fact minimizes any tendency for build-up of solids to occur in the valve. The branch of the valve isolated by the chute is effectively sealed by the chute seating on a durable flexible plastic joint. Where fibrous materials are being handled with the possibility of material

Fig. 1.—Two-way control valve in operation.

clinging to the edge of the chute during change-over, the flexibility of the joint enables a dust-tight seal to be maintained round the obstruction until the next change-over allows the material to be carried clear.

The mechanism for operating the valve is spring loaded and can be operated by either hand or remote control; it gives a rapid positive action which prevents the chute from taking up a position in which neither branch of the valve is sealed. All parts of the valve are readily accessible, and consideration has also been given to the design of the chute pivot bearings which are self lubricating and require no attention.

The valve made in a range of sizes to fit ducting of 4 to 22 in. diameter.

Polythene Bucket

A POLYTHENE bucket, resistant to acids, alkalis, and solvents is being manufactured by Tool Treatments (Chemicals) Ltd., Colliery Road, West Bromwich, Staffs. Practically unbreakable and very light in weight, this bucket holds 2 gallons and the contents can be measured on a scale on the interior of the bucket, A steel handle covered with P.V.C. sleeving is provided, and a specially designed spout facilitates accurate pouring and helps to regulate rate of flow.

Published by the Proprietors, INDUSTRIAL NEWSPAPERS LIMITED, and printed by CLEMENTS, NEWLING & CO. LTD., Priory Works, Alperton, Middlesex.